PROCEEDINGS

of the

American Society

for

Horticultural Science

for

1934

Volume 32

THIRTY-FIRST ANNUAL MEETING

J. R. MAGNESS

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OF THE

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FOR

HORTICULTURAL SCIENCE

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Sectional Chairmen......C. H. CONNORS, J. E. KNOTT, W. E. BRIERLEY
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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in an agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society, who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for membership. These officers shall be elected annually by ballot.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting.

SEC. 2. There shall be a Committee on Nominations consisting of five (5) members, who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this Committee, at the following meeting, to suggest to the Society nominees for the various committees, and one nominee for each of the offices for the ensuing year.

SEC. 3. There shall be an Executive Committee, consisting of three (3) members and the President and the Secretary, ex-officio. This committee shall perform the usual duties devolving upon such committee.

SEC 4. The committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them and to report the present status of the same.

*The Constitution and By-Laws as amended from time to time.

SEC. 5. There shall be a Committee on Program, consisting of three (3) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

SEC. 6. The annual dues of the Society shall be four dollars.

SEC. 7. Ten members of the Society shall constitute a quorum.

SEC. 8. There shall be an editorial committee consisting of five members. One member shall be elected each year to serve for five years.

SEC. 9. There shall be a committee on sectional groups and membership.

SEC. 10. There shall be a committee on local arrangements.

SOCIETY AFFAIRS

RESUMÉ OF THE ANNUAL MEETING AT PITTSBURGH, PENNSYLVANIA, DECEMBER 28, 29, AND 30, 1934

The thirty-first annual meeting was held at the Cathedral of Learning of the University of Pittsburgh. There were 12 sections, including a joint session with the American Society of Plant Physiologists and a joint session with the Potato Association of America. There was also a round table for extension workers. The dinner and social evening, with Dean R. L. Watts of Pennsylvania State College as Toastmaster, was held at the Hotel Webster Hall. Local arrangements were in charge of Professor F. N. Fagan.

CHANGES IN THE SOCIETY CONSTITUTION AND BY-LAWS

ARTICLE V of the Constitution was changed to read as follows: The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society, who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for membership. These officers shall be elected annually by ballot.

SECTION 2 of the By-laws was changed to read as follows: There shall be a Committee on Nominations consisting of five (5) members who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this Committee, at the following meeting, to suggest to the Society, nominees for the various committees, and one nominee for each of the offices for the ensuing year.

SECTION 3 of the By-laws was changed to read as follows: There shall be an Executive Committee, consisting of three (3) members and the President and the Secretary, ex-officio. This committee shall perform the usual duties devolving upon such committee.

SECTION 10 of the By-laws was added as follows: There shall be a committee on local arrangements.

REPORT OF THE COMMITTEE FOR SECTIONAL GROUPS AND MEMBERSHIP

This committee has followed the same procedure as in 1933. Local representatives have been asked to see all members and prospective members in their institutions. This method resulted in the addition of 45 members in 1933 and it is hoped that similar normal growth will be obtained for 1934.

A study of the membership situation shows a steady growth since the society was organized, altho there have been years in which memberships declined slightly in numbers, as in the war years. On the whole, however, the membership increment has followed a straight line relationship. Such a relationship indicates clearly that the *modus operandi* of the successive membership committees perhaps has been less effective than the general and sustained interest evidenced by the men working along horticultural lines.

RECORD OF MEMBERSHIPS, NUMBER OF PAPERS, AND THE RATIO OF NUMBER OF MEMBERS PER PAPER

Year	No. Members	Annual Gain or Loss	No. Papers	Ratio	
				Members	Papers
1903	—	—	10	—	-
1904	53	—	13	4.1	1
1905	53	—	14	3.8	1
1906	63	+10	11	5.7	1
1907	82	+19	13	6.3	1
	No program				
1909	80	—2	8	10.0	1
1910	85	+5	13	6.5	1
1911	111	+26	14	8.0	1
1912	143	+32	21	6.8	1
1913	172	+29	27	6.4	1
1914	179	+7	25	7.2	1
1915	190	+11	33	5.8	1
	(Includes California field meeting)				
1916	206	+16	16	12.9	1
1917	220	+14	40	5.5	1
1918	219	—1	28	7.8	1
1919	216	—3	38	5.7	1
1920	242	+26	54	4.5	1
1921	279	+37	55	5.1	1
1922	293	+14	51	5.7	1
1923	307	+14	61	5.0	1
1924	292	—15	80	3.6	1
1925	314	+22	83	3.8	1
1926	332	+18	90	3.7	1
1927	330	—2	73	4.5	1
1928	383	+53	99	3.9	1
1929	406	+23	90	4.5	1
1930	446	+40	140	3.2	1
1931	459	+13	156	2.9	1
1932	461	+2	154	3.0	1
1933	506	+45	160	3.2	1

That our membership should continue to increase in the future is evident from a study of the number of men engaged in horticultural work in the United States. The "Proceedings" for 1933 lists 506 members of whom 23 were from Canada, 25 from foreign countries, and 458 from the United States. A perusal of the available organization lists show in the state institutions and the various branches of the United States Department of Agriculture a total of 589 workers in horticulture. These figures indicate there were 131 workers in the horticultural field who were not members in 1933. It is obvious that the society may be able to increase its membership from this latter group.

Some progress has been made in obtaining associate members altho it is difficult at this time to note just how many names have been added to our list. Doubtless this class of membership will add many names to our list in the future.

Respectfully submitted,

W. G. BRIERLEY
M. B. DAVIS
G. H. BLACKMON
R. A. McGINTY
E. L. OVERHOLSER
ROGER CLAPP
R. J. BARNETT

Committee

REPORT OF RESOLUTIONS COMMITTEE

1. *Resolved,* that the Society express its thanks to the Webster Hall Hotel and its management in providing the splendid accommodations for the members and headquarters for the Society.

To Professor Fagan for the excellent arrangements made before and during the meeting leading to its success.

2. *Resolved,* that the American Society for Horticultural Science approves plans now being formulated looking toward the reorganization of the National Botanical Garden, making it national in scope and representative of botanical science pure and applied.

Resolved, further, that the Society bespeaks for the Garden such support by the Congress as may make possible the utilization of these plans for such a garden at the National Capital.

3. *Resolved,* that the Society express its especial thanks and appreciation to the members of the editorial committee who are giving so unselfishly of their time to the careful editing of papers published in the Proceedings.

4. *Resolved,* that a telegram of greeting be sent to Dr. E. J. Kraus, hoping for his speedy recovery from illness.

F. P. CULLINAN, *Chairman*
A. S. COLBY
J. C. MILLER

COMMITTEE ON PLAN FOR NATIONAL RESEARCH COUNCIL

It was voted that the President appoint a committee to formulate a plan to present to the National Research Council asking for assistance in carrying out a definite objective of the Society. The committee as appointed: J. R. Magness, *Chairman*, H. C. Thompson, W. G. Brierley, Alex Laurie, J. H. Beaumont, V. R. Boswell, V. R. Gardner, A. J. Heinicke, and F. E. Gardner.

COMMITTEE ON BROADENING PARTICIPATION OF MEMBERS

It was voted that a committee be appointed to study the question of providing for wider participation of the membership in the election of officers and in determining policies of the organization. The committee as appointed: W. H. Alderman, *Chairman*, E. F. Palmer, E. L. Overholser, H. A. Jones, E. C. Auchter, A. T. Erwin, A. J. Heinicke, J. H. MacGillivray, and Alex Laurie.

REPORT OF NOMINATING COMMITTEE AND ELECTION OF OFFICERS

In its report the nominating committee submitted the names of officers and committees as shown on page ix of these Proceedings. The Secretary was instructed to cast the vote of the Society for the officers and committees as nominated, and their election was declared.

TREASURER'S REPORT FOR 1934

Receipts

Dues (1934)	$1,960.00		
Reports sold (includes bound volumes)	870.26		
Extra pages purchased by authors	411.40		
Reprints and etchings sold	1,119.92		
		$4,361.58	
Interest on money in savings acct		35.56	
Balance on hand Dec. 20, 1933		1,706.78	
			$6,103.92

Expenditures

Dec. 27	Expenses to Boston meeting	$ 43.40	
Jan. 5	Postmaster, stamps and postcards	10.00	
Feb. 13	Postmaster, stamps and postcards	10.00	
Feb. 13	Mimeographing, etc	10.00	
Mar. 9	Humphrey Press, letterheads, programs, etc	54.25	
Mar. 9	Postmaster, stamped envelopes	68.16	
Apr. 21	Roy Magruder, postage	1.68	
Apr. 24	Secretary's office	250.00	
June 28	Postmaster, stamps	15.00	
July 24	Postmaster, postcards	5.00	
July 31	Express company, charge for sending Proceedings	1.16	
Sept. 13	Addressing envelopes for circular letter	3.00	
Oct. 19	Postmaster, stamped envelopes and stamps	25.00	
Nov. 1	Addressing statements	2.45	
Dec. 1	Addressing envelopes for programs	6.00	
Dec. 1	Postmaster, postcards and stamps	5.00	
	Humphrey Press, printing Proceedings	2,264.56	
	Humphrey Press, printing reprints, and includes charge for halftone and etching	686.74	
	Humphrey Press, bound volumes	34.00	
	Humphrey Press, express and postage, mailing Proceedings	75.18	
	Humphrey Press, billheads and membership folders	31.00	
	Total expenditures	$3,601.58	
	Balance on hand Dec. 20, 1934	2,502.34	
			$6,103.92

Respectfully submitted,
H. B. TUKEY, *Treasurer*

Audited and found correct, and books in excellent condition.

W. F. PICKETT
C. H. MAHONEY
Committee

Studies of the Little-Leaf Disease in California

By W. S. BALLARD, and ROBERT C. LINDNER, *U. S. Department of Agriculture, Fresno, Calif.*

THE characteristic symptoms and appearances of apple rosette and pecan rosette and of the little-leaf diseases of stone fruits, grapes, and various other woody plants have been described by a number of investigators (2, 3, 7, 11, 12, 13).

No one who has worked on any of these diseases has succeeded in establishing a causal parasite or virus, and most of the investigators have been strongly of the opinion that these troubles belong among the physiological diseases and are to be attributed to unfavorable climatic or soil conditions of one kind or another.

LITERATURE

Before the beginning of the present century Hilgard and Loughridge studied the tolerance of various plants to alkali in California. Loughridge (10) described and illustrated a typical case of apple rosette on a Jonathan tree. He interpreted the trouble as alkali injury and it seems quite possible that these two workers also saw cases of what we now call little-leaf on stone fruits and interpreted them in the same way. Smith and Smith (13) mentioned little-leaf of apples, pecan rosette, mottle-leaf of citrus and little-leaf of peaches, quinces and walnuts. They brought all of these diseases together in one general group and associated their occurrence with light soils, particularly if such soils are underlaid by coarse, sandy subsoils. They pointed out the greater prevalence of these diseases following unusually dry seasons and recommended regular and sufficient irrigation as the most important remedy.

Orton and Rand (12) were of the opinion that pecan rosette is due to "some lack of balance in the nutritive supply, or possibly to some toxic organic substances in the soil." Bioletti and Bonnet (2) made mechanical analyses of the soil and found a higher percentage of coarse material in the soil in which vines were showing little-leaf than in the closely adjacent soil in which they were growing normally, and they also concluded that lack of moisture is a characteristic of affected soils. Hodgson (8) supported Smith and Smith and correlated the unusual prevalence of little-leaf in 1918 with the exceptionally dry season of 1917. He was, however, of the opinion that little-leaf might possibly be associated with alkali.

Haas, Batchelor, and Thomas (7) grew walnut, pecan, peach and apricot trees in a space between two blocks of citrus trees that had been fertilized with nitrate of soda for 13 years. All of the deciduous trees developed little-leaf or rosette. This observation, together with data from ash analyses, were believed by the authors to indicate a close relationship between mottle-leaf of citrus and little-leaf of deciduous trees and vines. The authors called attention to the possibility that base exchange phenomena may be concerned in the development of these diseases, and they also include the possibility of toxic soil substances being the cause.

Morris (11) summarized the work done at the Washington Experiment Station, beginning as far back as 1911. In 1913 studies were commenced on the relation of soil alkali and humus to apple rosette. Chemical analyses brought out certain differences between normal and diseased shoots, but the pot culture work and soil analyses shed no light on the cause of apple rosette, and gave no indication that soil alkali had any direct bearing on the trouble. The bulletin ends with the statement that apple orchards planted to alfalfa for three years or more are practically all free from rosette. The more recently published work by Alben et al (1), Chandler et al (3, 4, 5), and Finch and Kinnison (6) on the effectiveness of zinc in correcting rosette of apples and pecans, as well as little-leaf of stone fruits and grapes, has introduced a new view point and has directed attention to a new line of attack.

The fact that zinc is a corrective for all of these diseases suggests strongly that they all have a common cause.

POT AND TANK CULTURES

During the years of 1924–26 the senior author grew grapes in pot cultures, both sand and soil, to which were added various amounts and combinations of a number of salts that might occur in alkali soils, the purpose being to induce little-leaf if possible. The higher concentrations of salts produced foliage injury, but no indications of little-leaf were to be seen in any of the several hundred cultures.

Dozens of other pot cultures have likewise given negative results, even when the soil was from a corral spot where little-leaf had killed peach trees, but in this case galvanized iron tanks were used and the failure can be attributed to the zinc coating as well as to zinc in the tap water used. Later experiments were conducted with this corral soil in which ordinary glass bottles of one gallon capacity were used and in which grapes grown from single bud cuttings were planted. Even though the cultures were watered with distilled water no little-leaf developed, either with one or three plants per jar.

GRAFTING, TRANSPLANTING, AND GROWING FROM CUTTINGS

In the spring of 1925 a small block of 8-year-old Malaga grapes growing in a corral spot, where they had been rendered worthless by the development of little-leaf, were cut off and regrafted with scions from healthy vines. A large amount of little-leaf reappeared during 1925, and nearly all the vines became involved in 1926. Thirty-five of these diseased vines were dug up in the spring of 1927 and replanted in a different locality. They promptly began to recover and in two years all signs of little-leaf had disappeared.

In another case diseased vines were replaced with healthy nursery stock, and in 2 years the replants were badly attacked by little-leaf. Similar results have been reported by Bioletti and Bonnet (2) with grapes, by Orton and Rand (12) with pecans, and by Morris (11) with apples.

Early in the spring of 1934 a large number of cuttings were taken from Alicante Bouschet vines which we knew to have been seriously affected with little-leaf in previous years. The cuttings were rooted

in coarse washed sand and were watered from a galvanized pipe line and rubber hose, which, of course, supplied them with a certain amount of zinc. The first leaves to appear on a number of these cuttings had the pointed lobes and intervenal chlorotic streaks characteristic of little-leaf grape foliage. Other cuttings produced foliage having intervenal chlorotic areas but without the pointed lobes, a condition which frequently obtains when normal cuttings are rooted in sand. A distinction between these two types is not always possible and the attempt to record the number showing the true little-leaf type was abandoned. In all cases the later foliage was normal in shape. When the cuttings were well rooted, 56 of them were planted in fertile potting soil in No. 10 tin cans, and 32 were planted in No. 10 cans of the same washed sand in which they had been rooted. The plants in the potting soil soon took on a good green color. The foliage was normal in shape and color, and each plant produced from 4 to 6 feet of growth. The vines planted in sand made only about 5 inches of growth during the entire season and the foliage was yellowish, but no little-leaf developed.

Little-Leaf and Rosette in Corral Spots

It is frequently noticed that typical symptoms of little-leaf on stone fruits and rosette on apples are to be seen on trees growing around barn-yards and feeding grounds. It also happens quite commonly that a piece of land planted to orchard may include a plot of ground previously occupied by a barn-yard or stock feeding ground. In the latter case, the trees or vines on the site of the old feeding ground are very apt to develop marked little-leaf symptoms.

Such spots in an orchard are commonly called corral spots, and the diseased trees or vines are sometimes said to suffer from "corral spot sickness," but in our opinion the trouble is identical with little-leaf and rosette. Whatever the changes may be that take place in such plots of ground, the effects persist for many years.

In 1931, we were given access to such a corral spot located near the center of a large block of peaches. The original peach trees had died or been pulled out on account of little-leaf and replants had gone the same way. In the spring of 1931 the owners of the ranch replanted this corral spot with seven varieties of fruits and nuts, according to our suggestions. The varieties selected were Early Harvest apple, Muir peach, Yellow Egg and Kelsey Japan plums, Malaga grapes, seedling pecans, and Payne's Seedling walnuts. Twelve and 14 trees of each of the tree fruits and nuts, and 24 vines of the grapes were planted in the spaces originally occupied by the peach trees, and the planting was so mixed as to scatter each variety as uniformly as possible over the entire area. Two vines were planted in each of the spaces occupied by the grapes.

Some replanting has been necessary, especially of Kelsey Japan plums, Payne's Seedling walnuts and Muir peaches. All of the plums and peaches are on peach root, the seedling pecans and Malaga grapes are on their own roots, the walnuts are on California black walnut roots and the apples are on apple seedling roots.

During the first year, 1931, no little-leaf or rosette symptoms were

noticed; but in 1932 there was unmistakable evidence of disease on peaches, plums and pecans. In July, 1934 the percentage of trees or vines of the 7 varieties showing little-leaf or rosette was as follows: Kelsey Japan plum 100 per cent, seedling pecan 100 per cent, Muir peach 92 per cent, Yellow Egg plum 75 per cent, Early Harvest apple 50 per cent, Payne's seedling walnut 25 per cent, Malaga grape 23 per cent. As the planting grows older greater percentages of the less susceptible varieties will become diseased. All of the plums and peaches are on peach root and yet the tops, that is, the varieties themselves, show considerable variation in their susceptibility to little-leaf. The above figures afford a general idea of the susceptibility of these fruits and nuts to little-leaf and rosette and indicate the rapidity and seriousness with which corral spot planting may become involved.

Lipman (9) has compared the analyses of a water extract of soil from a corral spot where chlorotic citrus trees were growing with that of soil from the adjacent area where trees were growing normally. He also compared his findings with the data of Kelley and Cummins on ash analyses of normal and mottle-leaf citrus foliage.

Effect of Alfalfa on the Development of Little-Leaf in Grapes

The effectiveness of clover and alfalfa cover crops in controlling apple rosette was probably discovered by the apple growers in the Yakima district in Washington about 1910. Chandler et al (3) and others have observed that an alfalfa cover crop reduces little-leaf of stone fruits in California.

There are a number of practical difficulties connected with growing alfalfa in a vineyard, but in 1931 we induced one owner to try the experiment in a 2-acre block of Zinfandel grapes that were then two years old and in which 22 per cent of the vines were showing at least a trace of little-leaf.

The intention was to plant half the block to alfalfa and keep the other half clean cultivated, but unfortunately we have 24 rows in alfalfa and four in clean cultivation, with a buffer row between. The clean cultivated plot is on the side of the block where comparatively few cases of little-leaf had developed at the time the experiment was started.

We have a system for recording in some detail the condition of a vine with reference to little-leaf, but for our present purpose we need consider only two groups "commercially good" and "commercially bad." The alfalfa seed was planted in the fall of 1931 but did not germinate until the spring of 1932. The percentage of "commercially bad" vines in the alfalfa plot has decreased from 17.6 per cent in July, 1932 to 6.1 per cent in August, 1933 and 5.1 per cent in August, 1934. The percentage of "commercially bad" vines has increased in the clean cultivated plot from 5.4 per cent in July, 1932 to 9.5 per cent in August, 1933 and 26.5 per cent in August, 1934. Thus the growing of an alfalfa crop in this vineyard, even though the cuttings were removed, appears to have materially reduced the amount of little-leaf that probably would otherwise have developed.

Soil Treatments for the Control of Little-Leaf

Experiments were begun in 1927 in which solutions of various chemicals were introduced into the soil around little-leaf vines. Some two dozen inorganic salts and acids were tried, including zinc and iron salts. Over 750 applications were made, but no effects were obtained, and it has since become evident that the amounts used were too small.

In the summer of 1929 over 500 trees and vines, the latter in sandy soil, were treated by applying various salts to the soil. No improvement could be observed during 1929, but in 1930 a few young vines that in 1929 had received 5 pounds of commercial iron sulfate in 50 gallons of water and poured into basins around the trunks remained free from little-leaf throughout the year. Other similarly treated vines in the same block showed no improvement, and older vines that had received as high as 20 pounds of iron sulfate per vine showed no improvement. Two young vines in this sandy soil that had each received 2 pounds of zinc sulfate in 50 gallons of water in 1929 showed no little-leaf in 1930, but since an occasional vine may show little-leaf one year and be practically free from it the next, it seemed more probable that these were two such cases of vine variation.

Since 1929, spring and summer applications to the soil have been continued, mostly in sandy land, and the experiments have been confined chiefly to grapes and plums. During 1930 a smaller number of soil applications were made, and in these the commercial iron sulfate used was of American manufacture. The results were inconsistent, as they had been in 1928 and 1929. Some vines showed marked response and others showed no improvement at all.

During the spring and summer of 1931 the materials used included iron sulfate, manganese sulfate, potassium sulfate, ammonium sulfate, ammonium phosphate, sulfuric and nitric acids. It had been found that spring and summer treatments with commercial iron sulfate might produce no results during the year in which they were applied, but in the following year such treated vines might be free from little-leaf. However, in many cases, 10- and 20-pound dosages of iron sulfate applied to young vines in 1931 produced no response in 1931 or 1932. The iron sulfate that we used in 1931 was chiefly a Belgian product and the explanation of our failures is no doubt to be found in the discovery made by Chandler et al (3) in their extensive series of experiments in which they used this Belgian product with such poor results; namely, the Belgian iron sulfate carried much less zinc impurity than did the American product, and it was the zinc impurity in the American iron sulfate that was correcting the little-leaf.

In 1932 we applied zinc sulfate and other materials both in solutions poured into basins around the trunks and as dry salts in trenches and washed down by irrigation. Again our results were not consistent in that 5 pounds of zinc sulfate did not always cure little-leaf of grapes in the same block where 5 pounds of commercial iron sulfate had previously been effective, and one pound of zinc sulfate, an amount of zinc far greater than would have been contained in an effective dosage of the original iron sulfate, produced no improvement in the vines at all. Chandler et al (5) have had similar experiences.

In February and March, 1933, zinc sulfate and other materials were applied to the soil in several vineyards and in an orchard of Becky Smith plums grafted on old Climax trees. The soil in all cases was a sandy loam. Vines treated with 10 pounds of zinc sulfate on February 24, 1933 were free from little-leaf when notes were taken in June of the same year, but 5-pound dosages did not produce complete recovery in all cases.

On the other hand, the plums treated on March 2, 1933 with amounts of zinc sulfate up to 15 pounds per tree showed very slight and questionable improvement in 1933, but many of them were practically free from the disease in 1934. Some trees that had received 5 pounds of zinc sulfate in 1933 and had shown no material improvement that year came out normally and were practically free from little-leaf in 1934. Others that had received the same dosage showed very little if any improvement, even in 1934. The same differences in response were obtained from the 10- and 15-pound dosages. Two and one-half pounds or less of zinc sulfate had no effect, and no doubt 15 pounds, if rapidly washed into a sandy soil by an excess of irrigation water, might lose its effectiveness simply by dilution.

Dosages of 1, 5, 10, and 15 pounds of zinc sulfate were applied in trenches near the trunks of some old vines in sandy soil. The applications were made on February 28, 1933 and no effects were noticeable during that entire year, but in 1934 it was evident that the 10- and 15-pound dosages had caused marked improvement; in fact, nearly all of those vines were practically free from little-leaf. Some of the vines that had received only 5 pounds in 1933 were entirely free from little-leaf in 1934, but others showed only slight improvement. One-pound dosages had no effect at all.

Soil Treatment During the Growing Season

Four varieties of plums growing in sandy soil were treated with 5 to 10 pounds of zinc sulfate on April 5, 1934 when the foliage was well out. Only a very slight amount of foliage burning developed after this application, but in another orchard on much heavier soil 10-, 15- and 20-pound dosages of zinc sulfate applied to Kelsey plums on March 30, 1934 caused serious burning and dropping of foliage from some trees, but the amount of injury bore no relation to the quantity of zinc sulfate applied. The zinc sulfate solution soaked into this heavy soil much more slowly than into the sandy one and the surface roots had a greater opportunity to absorb the concentrated solution. Some surface roots were injured in digging the trenches in which the zinc sulfate was applied.

Miller's Late peaches in sandy soil developed some foliage burning and dropped some turgid green leaves following an application of 5 pounds of zinc sulfate on April 5, 1934. Late in the season the foliage on these zinc treated peach trees was much greener and hung on better than that of the adjacent untreated little-leaf trees.

Grapes having trunks about 3 inches in diameter and growing in sandy soil have been treated with as much as 30 pounds of zinc sulfate dissolved in 50 gallons of water, the solution being run into trenches 8 inches deep and 15 inches out from the trunks. This application was

put on in June and no foliage injury developed during the remainder of that year or during the following year.

Thus various fruits show marked differences in their susceptibility to injury from soil applications of zinc sulfate put on during the growing season. The type of soil, the area covered by the application and the amount of water applied are also very important factors. It appears that if the soil treatment method is to be practiced the applications should be put on during the dormant period. We have found that even in a sandy soil the amount of water used for soil treatments may penetrate very unevenly, and of course the main roots from a tree or vine may be very unequally distributed. When all these factors are taken into consideration, we perhaps have no right to expect uniform results from soil treatments.

Other Chemicals Used in Soil Treatments

In addition to iron sulfate and zinc sulfate, we have tried other materials in our soil treatment experiments, among which have been salts of aluminum, ammonium, copper, lead, magnesium, manganese, nickel, potassium, titanium, and also borax, sulfuric acid, nitric acid, and sucrose. Occasionally some of these compounds have appeared to reduce little-leaf somewhat, but none of them have done so consistently. Many normal vines have been treated with some of these same chemicals in the hope of inducing little-leaf but thus far without success.

Direct Introduction of Chemicals

In 1929 we attempted to determine if iron introduced directly into the trunk of a vine would have any effect on little-leaf. Small quantities of ferric ammonium citrate were pipetted into holes bored in the arms of little-leaf vines, and the dry salt was also introduced in a similar manner. Our results were negative and at that time we suspected that the failure might be due either to an insufficiency of iron introduced or its failure to be translocated.

More recently we have introduced measured quantities of various compounds into holes bored in the trunks or framework portions of vines and trees. Of the 45 inorganic and organic compounds tested only the readily soluble zinc salts have thus far produced unmistakable results.

Apricot trees were treated on October 10, 1933. Two to four holes 5/16-inch in diameter were bored in limbs 3 to 4 inches in diameter. One or two main limbs on a tree were treated and one or two were left as checks. The limbs treated with zinc sulfate received 0.15 to 0.60 grams of zinc sulfate per hole, or a total of 0.60 to 1.80 grams per limb. A slight amount of foliage burning developed above the holes. In the spring of 1934, after the foliage had come out, the treated limbs with their abundant, large, dark-green leaves stood out in sharp contrast to the untreated limbs that produced a sparse growth of small yellow leaves. Even the smallest amounts of zinc sulfate produced marked results, but it was possible to find one or more little-leaf shoots on all of the treated branches.

Trees as badly diseased as these were, never produce much fruit,

and that was the case with the check limbs on our experimental trees, but the treated limbs produced a few normal apricots. At the same time that the zinc sulfate was applied, other trees were similarly treated with zinc oxide, zinc sulfide and powdered metallic zinc. We have not been able to see any improvement in the trees treated with these last three materials.

A striking effect from zinc sulfate was obtained on a vine that was completely involved in little-leaf. The trunk was about 6 inches in diameter at the ground line, and at that level six holes were bored, into each of which about 0.45 grams of zinc sulfate was introduced on September 19, 1933. Six weeks later the entire vine was covered with a new growth of healthy young leaves. Surrounding healthy vines and the untreated arms on an adjacent little-leaf vine had practically stopped growing when this zinc treated vine put out the flush of new growth which completely covered it. It continued to grow until frost came in the latter part of November. No foliage burning resulted from these treatments at the ground line.

On January 25, 1934 a series of healthy vines having trunks about 3 inches in diameter was treated with zinc sulfate in amounts from 3 to 15 grams per vine. Even the 15-gram dosage did not prove toxic. On March 15, much bleeding was taking place at all the holes where the zinc sulfate had been introduced, but there was no evidence of foliage injury and the leaves were coming out more rapidly on the treated vines than on the adjacent untreated ones. It appeared that the treated vines set a larger crop of fruit.

The experiments which we have reported demonstrate the striking way in which the effects of zinc on little-leaf can be brought out by this method of introducing it into woody plants. From a practical standpoint the method cannot be recommended except perhaps for the treatment of an occasional tree. Treated trees or limbs that had produced an abundance of good foliage during the spring and early summer outgrew the effects of the zinc and were sending out typical little-leaf growth and foliage before the end of the growing season.

The method is slow and therefore expensive, especially if the treatment lasts for only a year or two, and there would seem to be danger of wood-rots becoming established, although a similar method of treating chlorotic pear trees with iron compounds is in commercial practice.

Spraying Experiments

In 1933, grapes were sprayed with 8–8–50 zinc-lime mixture. Very little improvement could be seen. Weather conditions probably have much to do with the action of this type of spray. In the Fresno district rain, fog and dew are uncommon during the summer.

In the summer of 1934 grapes were sprayed with zinc-lime mixture, zinc oxide, zinc sulfide, zinc sulfate, zinc oxide plus zinc sulfate, zinc sulfide plus zinc sulfate, zinc acetate and zinc sulfate plus ammonia. The zinc oxide and zinc sulfide were the finely ground commercial materials used in the manufacture of paints and in the rubber industries. Casein spreader was used.

The first spraying was applied May 12, when the vines were out

far enough so that little-leaf was clearly evident. The results from 6–6–50 zinc-lime mixture were not at all striking, in fact zinc oxide and zinc sulfide produced better recoveries and more new growth. Zinc sulfate alone is apt to burn except in very low concentrations, and the object in combining zinc sulfate with zinc oxide or zinc sulfide was to obtain the quick effect from zinc sulfate and depend upon the oxide or sulfide to gradually give off small amounts of soluble zinc over a long period.

It was thought that zinc sulfide might gradually go over to the sulfate and furnish a continuous small supply of soluble zinc, but the results did not indicate that this took place to any appreciable extent.

Ten pounds of either zinc oxide or zinc sulfide plus 6 ounces of zinc sulfate and a suitable amount of casein spreader in 50 gallons of water produced marked improvement. The chlorotic leaves became green and new growth was sent out. The effect lasted about a month, after which little-leaf growth began to appear. Three pounds of zinc sulfate and 5 pints of "stronger ammonia water" in 50 gallons of water gave very striking results which lasted about 2 months. Zinc acetate did not prove very effective.

On plums zinc oxide plus zinc sulfate, and the zinc-ammonia sprays gave better results than the zinc-lime mixture. On pecans sprayed August 24 the zinc-ammonia solution gave the best results, and zinc tartrate seemed to have no effect at that time of year.

The zinc-ammonia spray has produced some striking results, but there is a possibility of foliage injury developing in damp or rainy weather. The foliage of the various fruits react differently to these various sprays and further work is necessary before definite conclusions can be drawn.

It was thought that a mixture of sulfur and finely divided zinc oxide might be effective as a dust, but an application on plums and grapes put on in the middle of August produced no improvement.

Cause of Little-Leaf Not Yet Determined

These little-leaf and rosette diseases can be corrected by introducing a sufficient quantity of zinc into the trees or vines, and the method of introduction may be by means of soil applications or through holes bored in the above ground woody portions or by spraying. Whether the action of the zinc is direct or indirect remains to be determined, but the indications are that these troubles are zinc deficiency diseases, though the final settlement of the question rests upon growing susceptible plants in a zinc-free culture medium.

We have had occasional cases in which manganese sulfate or sulfuric acid applied to the soil appeared to have some beneficial effect, but such exceptional cases might be attributed to base exchange or to direct chemical action or more probably to individual variation among vines.

The results from the transplanting and grafting experiments and the growing of healthy vines from cuttings taken from little-leaf vines support the belief that the diseases are not caused by parasites or a virus.

If the diseases are caused by some deleterious substance either

taken up from the soil or produced within the plant as a result of the unfavorable soil environment in which it is growing, it would seem as though some of the other metallic ions that have been experimentally introduced into the plants should have precipitated or otherwise rendered such a foreign substance innocuous.

If we are dealing with zinc deficiencies, then the action of cover-crops, such as alfalfa, in preventing the development of these diseases will require explanation from that standpoint, and the association of little-leaf with coarse, sandy subsoils will demand consideration.

Finally, it may be worth while to state again that no one has reported a definite case of an annual plant showing little-leaf characters or evidences of zinc deficiency.

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Little-leaf or Rosette of Fruit Trees, IV

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IN preceding papers (1, 2, 3) we have described symptoms and some of the problems presented by this disease, have compared our observations with those of workers in other sections, and have described our methods of attack. It is the purpose to report in this paper only some additional observations that may be of interest to others who are studying little-leaf and related problems.

Further Observations Concerning Responses to Treatments

Applying zinc compounds to the soil:—In nearly all California soils the fixing power for zinc is so high that treatment with zinc compounds applied to the soil is too expensive and the results are uncertain, especially with trees such as the walnut, many of which have only very small fibrous roots within a foot or more of the surface, so that much soil must have its fixing power overcome before any zinc can reach roots of the size that seems to be required for absorption of enough zinc to correct little-leaf. A high fixing power for zinc in the soil does not merely increase greatly the amount of zinc necessary to cure a tree, it also reduces the time during which the tree remains healthy: in a soil having a fixing power for zinc of less than 200 parts per million, 3 pounds of zinc sulphate applied within 2 feet of the trunks and partly against them have kept trees such as those of the peach, large enough to occupy a space 20 x 20 feet, nearly all healthy for 3 years; in soils with a fixing power as high as 1000 parts per million, 20 to 25 pounds so applied can not be depended upon to keep a tree healthy longer than 1 or 2 years.

Large quantities of ferrous sulphate with the zinc sulphate reduce the amount of zinc sulphate that it is necessary to apply (3) and prolong the benefit. Treatment with 35 to 100 pounds of impure ferrous sulphate containing zinc equivalent to 2 to 6 pounds of zinc sulphate kept trees free from little-leaf more than twice as long as treatment with 5 to 25 pounds of zinc sulphate alone. However, quantities of ferrous sulphate small enough to be economically feasible, about 5 pounds to the tree, did not reduce measurably the amount of zinc sulphate necessary to correct a tree.

Last year (3) we reported apparently increased benefits from zinc sulphate when 10 to 20 pounds of gypsum or 5 to 10 pounds of ammonium sulphate to the tree was added with it, but during this year some of these trees have gone back into little-leaf as badly as trees treated with zinc sulphate alone. During 1934, many more trials have failed to show any benefit from adding, with the zinc sulphate, 10 to 15 pounds to the tree of gypsum or of aluminum sulphate. For example, 8 to 12 pounds of zinc sulphate with 15 pounds of gypsum or aluminum sulphate, applied close to the trunks, failed to cure young walnut trees less than 5 inches in trunk diameter.

Spraying with zinc compounds:—Peach, apricot, plum, and walnut trees have been sprayed on the young foliage in spring and early summer with a zinc-lime mixture, usually about 10 pounds of zinc sulphate with 5 pounds of hydrated lime in 100 gallons of water. All except the walnut have been benefited, the apricot most of all, but none have responded nearly so well as citrus trees. Grapevines showing little-leaf have uniformly made striking response to spraying with zinc-lime in early summer to midsummer, but tend to show bad little-leaf again the next spring.

Peach, apricot, plum, apple, and walnut trees have been sprayed on the mature foliage in autumn with 16 to 32 pounds of zinc sulphate in 100 gallons of water, with and without lime. There was no strong evidence of response by walnut trees. All the others came out in the spring following with healthy foliage, and stone fruit trees set a much better crop of fruit. On trees in soils that cause only spring little-leaf, with no summer mottling, this seems a satisfactory remedy, but on trees in the worst soils it does not prevent serious late summer mottling and does not insure normal development of fruits that ripen as late as August.

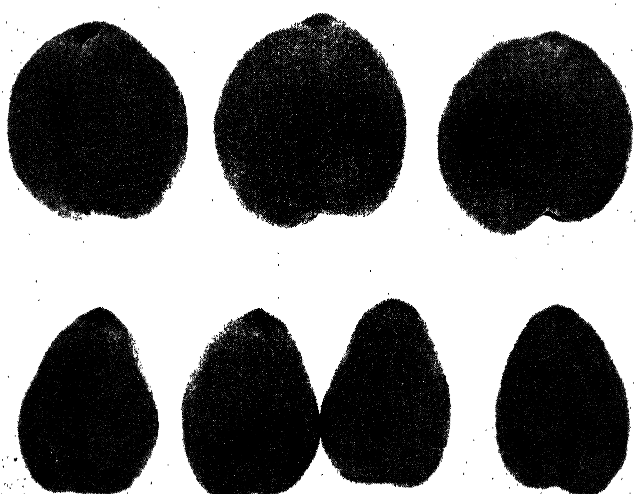

FIG. 1. Elberta peaches; upper row, normal; lower row, borne on trees very bad with little-leaf. Abnormal fruits are borne on all kinds of fruit trees if little-leaf is bad, but this effect is different with different kinds. Bad apricot trees bear very small fruit that is more nearly round than normal fruit. Grapevines even moderately affected may bear small, loose clusters with many small, "shot", berries. (Photograph by L. R. McKinnon.)

Trees have been sprayed also in the dormant season. The best responses were obtained by Mr. J. C. Johnston, who sprayed Japanese

plum trees, in Tulare County, just before the buds burst, with a strong zinc sulphate solution, 1 pound to the gallon of water, and by Mr. E. F. Serr, who sprayed peach and apricot trees, in San Joaquin County, with ¼ to 2 pounds of zinc sulphate to the gallon of water and one walnut tree with 2 pounds to the gallon, to which it seemed to respond well. One-fourth pound to the gallon was not strong enough for the worst trees, but it caused almost completely healthy growth until midsummer. Higher concentrations caused all trees, even the worst, to be free from little-leaf or mottle-leaf in spring and until midsummer or later, but the worst plum trees showed mottling and distortion in the latest growth of the summer, too late, however, to prevent the maturing of normal fruit. Very bad peach trees, in another county, sprayed in February 1934 with 40 pounds of zinc sulphate and 15 pounds of hydrated lime in 100 gallons of water, made normal spring growth instead of rosettes, and normal growth until nearly midsummer, when new leaves began to be mottled and distorted. The fruit, Phillips Cling, a late ripening variety, did not all develop well. As might be expected, this concentration of zinc sulphate and lime, a rather thick paste, was not as effective as ¼ pound to the gallon of zinc sulphate without the lime. Use of lime seems inadvisable for dormant spraying of deciduous trees.

The beneficial effect of dormant spraying with zinc sulphate should be greater after a second annual spraying. There is more young wood to absorb the zinc, and there are more buds to grow, so that less growth tends to be made from one bud. Zinc enough to last through the season might, therefore, be absorbed for each new shoot. Trials are being continued to see if, after a few years, one spraying a year with a moderate amount of zinc sulphate may not keep trees healthy in the worst little-leaf soils.

Brushing with strong zinc sulphate solution soon after pruning:— Grapevines very bad with little-leaf were brushed with a solution of 2 pounds of zinc sulphate in a gallon of water, immediately after pruning. They set and matured good clusters and made healthy growth throughout the summer, although adjacent check vines, carefully selected the summer before, bore no healthy leaves and only a few clusters of small "shot" berries. One pound to the gallon did not seem to be enough. No buds were injured by 2 pounds to the gallon. In a preceding year all spurs were killed by a much stronger solution. A gallon of solution covered 40 to 60 head-pruned vines large enough to have trunks about 3 inches in diameter. The method has not been tried on cane-pruned vines. Covering the vines thoroughly with a solution of 2 pounds of zinc sulphate to the gallon just before they were pruned caused only slight benefit. Apparently it requires the pruning wounds to get enough zinc into the vines, and there is some evidence that if these wounds stand a few days before treatment the results will not be nearly so good.

On trees, the pruning wounds do not seem to be such an aid to intake of zinc: when wounds were painted with zinc sulphate, or even with zinc chloride, there was no benefit to branchlets more than 15 to 20 inches above the wounds, though brushing the twigs and buds with the solution caused the tree to be healthy for one growing season.

Driving zinc-coated nails and pieces of zinc into the wood:—Of trees, or branches, and vines that in June 1933, or later in the summer, had zinc-coated nails or pieces of zinc driven into them (3), or zinc oxide placed in holes in them, those which had responded in the summer of 1933, and most of those which had not, started healthy growth in the spring of 1934. All continued healthy during the summer of 1934, except those treated with zinc oxide, one small peach tree, and one peach tree sucker. These last two grew enough to make the 3 and 4 pieces of zinc too few for their tops. Both were made healthy by retreatment.

A considerable number of trees or branches of walnut, peach, plum, apricot, apple, and other kinds of trees, and grapevines, were treated by driving into the trunks zinc-coated nails ⅛ inch, No. 2 glazier's points ¼ inch, No. 0 glazier's points ½ inch, or larger zinc pieces 1 inch, apart. Some treated walnut trees were too large for one circle of pieces these distances apart to cure them. Experience with this treatment is the opposite from that with spray treatment but in agreement with soil treatment: the amount of material required is determined much more largely by the size of the tree, the distance zinc must be transported, than by the severity of the little-leaf. Most of the walnut trees, however, and all the other trees or branches, and grapevines, showed improvement at the time little-leaf is conspicuous in spring or early summer; and all except some peach trees that were killed or injured by the treatment showed improvement throughout the summer.

FIG. 2. Carignane grapevines: vine at the right showing severe little-leaf; vine at the left, formerly as bad, was treated in January before this photograph was taken (July 7) with zinc glazier's points ¼-inch apart around the trunk. Note fairly good clusters of fruit even on this vine that, in the preceding year, bore only foliage as weak as that on the vine at the right. Brushing the vine immediately after pruning with 2 pounds of zinc sulphate in a gallon of water gave as good results at less cost. (Photograph by L. R. McKinnon.)

When it was found that pieces of zinc as small as No. 2 glazier's points were effective, a search was made for a device to drive zinc pieces rapidly. A No. 2 diamond point driver was obtained from a building materials company. This does not drive its diamond-shaped points as deeply as we had been driving No. 2 triangular points, but tests on walnut trees showed that diamond points penetrating through the bark and only slightly into the sapwood were more effective than the same number of zinc-coated nails driven at least a half inch deeper. However, sometimes they would not go deep enough to hold in the sapwood and would fall out after a few weeks, owing to the spreading of the cut bark. This implement was not obtained until after the season's growth had started, but a considerable number of trees and branches were treated between April 24 and July 7. These nearly all showed striking improvement and have continued healthy.

Tests were made to see how many zinc points would be necessary to cure a tree. On walnut trees killed back each year to a height of 7 or 8 feet, so that the trunks were large in proportion to the tree height, 4 points to the inch of circumference were enough for quick and striking response, as shown in Fig. 3. On trees with branches 12 to 15 feet long, or longer, it took 7 or more points to an inch of circumference to cause as good response. Because the bark is thinner on the branches than on the trunk, and because the nearer the foliage the points are driven the better the response seemed to be, we have usually driven these diamond points around the branches. They were not driven in one ring, but were scattered along the trunk or branch to place them an inch apart in all directions, for by midsummer we had learned that when placed much nearer than an inch from each other they may cause injury to some kinds of trees.

Citrus fruit trees also were treated and responded very slowly, when at all, to this method of treatment. In June 1933 a number of orange tree branches, and in the autumn and winter, 1933–34, a considerable number of orange tree trunks, were treated with zinc pieces. By October 1934 none were showing the slightest evidence of benefit. The trees were no larger than peach and walnut trees that would have been cured in a few weeks by the same numbers of pieces. The one tree reported as benefited in 1933 (3) continued healthy in 1934, but it had been killed back repeatedly by little-leaf so that its top was small in proportion to trunk circumference. We have had good response to zinc glazier's points driven into the trunk or branches of trees of *Juglans Hindsii,* fig, pecan, Carolina poplar, Melia, and Ligustrum.

It was thought that driving zinc pieces into a tree would be the safest possible treatment, but early in the summer of 1934, a walnut tree in which No. 0 glazier's points were driven a half inch apart showed killing in the bark between many of them, although there was cambium and bark enough left to keep the tree alive and healthy in appearance so far. By July 1934 most of the peach trees in which zinc pieces or zinc-coated nails had been driven ⅛ inch to ½ inch apart around the trunks were pale green in color, as a ringed tree would appear. By August some of them died. Others died later. The remainder are badly injured and will probably die. No serious injury

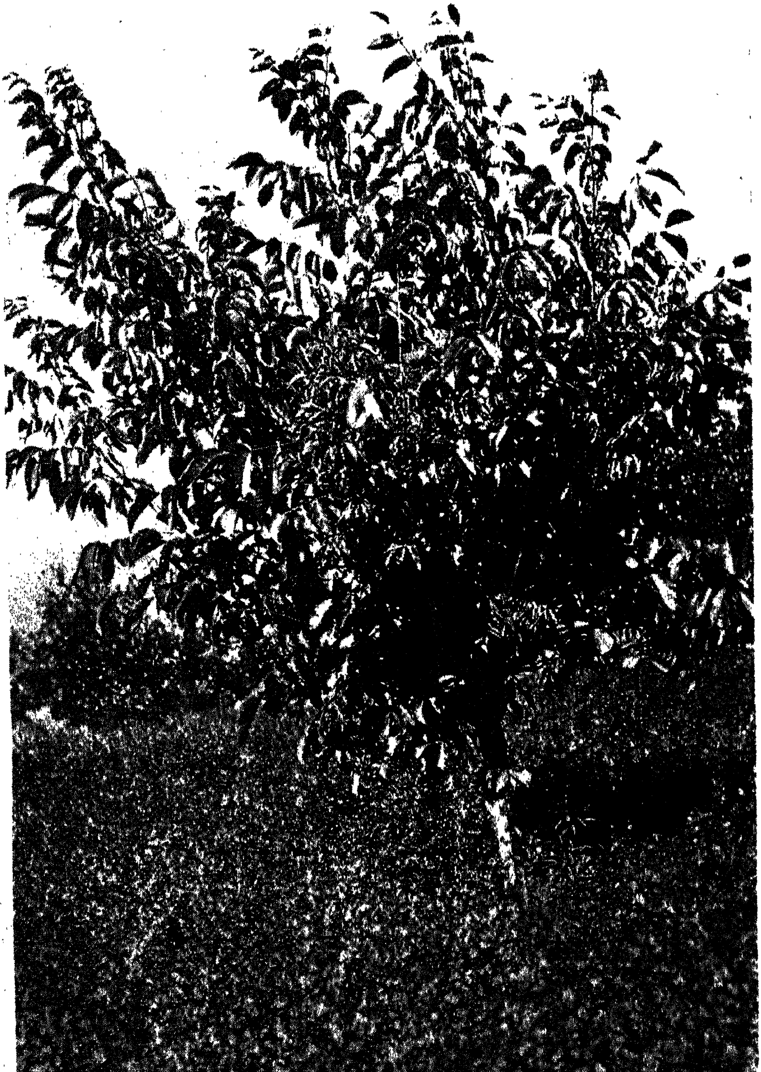

FIG. 3. Walnut tree formerly bad enough with little-leaf for the branches to be killed back to short stubs each year. It was treated April 24, 1934, on the trunk above the lowest branch with the small, diamond-shaped, zinc glazier's points, 4 to the inch of circumference. At "a" is the shoot growth from the untreated branch. The shoots bearing healthy leaves are the effect of the zinc pieces 74 days after the treatment. (Photograph by L. R. McKinnon.)

to grapevines, or to trees of apple, apricot, or plum, has been observed when zinc-coated nails or zinc pieces have been driven this close together, and no serious injury, even to peach or walnut trees when the zinc pieces were driven an inch apart.

The killing was in the bark and wood between the nails or zinc pieces. There was apparently no killing of streaks of bark or wood above the zinc pieces, or of leaves and shoots on some branches, such as sometimes results from soil treatment.

In Table I is a summary of analyses for zinc in parts of some trees treated with zinc-coated nails or zinc pieces.

TABLE I—ZINC CONTAINED IN BARK AND WOOD NEAR ZINC PIECES AND DIFFERENT DISTANCES FROM THEM

Material	Zinc (Parts per million, dry weight of tissue)	
	Bark	Wood
Peak peach trees killed by rings of zinc pieces or zinc-coated nails		
Tissue between the zinc pieces in the ring	6800–14800	2100–5600
Three-fourths of an inch above the zinc pieces	290–315	235–290
Three-fourths of an inch below the zinc pieces	155–1070	315–425
Tissue between pieces in the ring, but tissue that touched the zinc cut off to exclude zinc not in tissue	6500	700
Six inches above the zinc pieces	126–400	79
Six inches below the zinc pieces	160–288	112
Gravenstein apple tree branches treated August 31, 1933; samples taken November 8, 1934. Only slight injury within ⅛ inch of zinc pieces		
Tissue between the zinc pieces	4400	1540
Tissue half an inch above zinc pieces	60	135
Tissue half an inch below zinc pieces	45	130
Tissue 6 inches above zinc pieces	20	8
Tissue 6 inches below zinc pieces	18	9
Shoots from treated branches (Leaves = 32—32 p.p.m.)	12–31	44–16
Shoots from untreated branches (Leaves = 9.3 p.p.m.)	3.9	3.4
Gum from uninjured peach trees at zinc pieces	2700–5400	
Gum from uninjured apricot trees at zinc pieces	3000–3400	

Such slow removal of zinc from tissue near the zinc pieces seems hard to explain. The first suggestion was that fragments of zinc or of zinc oxide may have been rubbed from the surface when the pieces were removed; but there were still 6500 parts per million of zinc in peach tree bark after all tissue in contact with the zinc, including the gum that surrounded it, was trimmed off. The reduced zinc content in the wood after such trimming may suggest that much of the zinc in the wood between the zinc pieces was in gum that had been pushed into spaces and dead areas around the pieces.

The lack of injury except to a slight amount of tissue from several thousand parts per million of zinc near the zinc pieces, the high content of zinc in gum that passed over the zinc pieces, and the slow movement of zinc out of the tissue near the zinc pieces, suggested to us that much of the zinc may be lodged in the cell walls. Professor T. E. Rawlins of the Division of Plant Pathology, and Mr. L. O. Lawyer, are working on this problem, but so far they do not feel certain concerning results with any reagent tested. The best one found indicates that the largest concentration of zinc is in the walls of the dead cells and the protoplasm of the living cells. They hope to publish their results elsewhere later.

Before we can be certain concerning the value of zinc pieces driven into the tree, as compared with other treatments for little-leaf, we must have more evidence concerning the danger of injury and we must know how long the effect of a treatment will last. We do not yet know whether or not zinc can be dissolved from a piece imbedded completely in sapwood. Nails can be left sticking out an inch or more and will be in contact with bark for more than a year, but glazier's points may be completely in the sapwood after a few months of tree growth.

Treating one branch on a tree with zinc-coated nails or glazier's points and leaving other similar branches on the same tree untreated is the most convenient method we have for determining whether or not an abnormality in an orchard is little-leaf.

Little-Leaf Without the Characteristic Symptoms

Typical little-leaf rosettes show most clearly in spring on trees that made rather long shoot growth in the preceding summer. On unpruned old or weak trees, diagnosis may sometimes be uncertain. Soil treatments with zinc sulphate gave evidence, for cherry and almond trees in San Joaquin County and for J. H. Hale peach trees in Fresno County, that a tree may be making a weak growth as a result of whatever it is that zinc corrects, when it shows neither the characteristic spring rosettes of little leaves nor the summer mottling of leaves. This condition may, possibly, be rather extensive in almond orchards. Almond trees tend to make weak growth in many sandy soils but show characteristic little-leaf symptoms only in soils in which peach or plum trees would be exceptionally bad.

Concerning the Cause of Little-Leaf

Last year (3) we reported behavior of some peach trees that suggested an improvement caused by compounds of manganese and of chromium. This year, however, after treating individual branches, carefully selected the summer before, several each with manganous sulphate, with potassium permanganate, with chromic sulphate, and with potassium chromate, we can be certain that there was no recovery from little-leaf.

None of the organic or inorganic compounds used in preceding years (3) to test the possibility of curing trees of little-leaf by changing the soil flora, or by causing other changes in the soil, have caused any improvement. Neither have any of the substances, besides zinc or zinc compounds, placed in holes in the trunks of trees.

This year the following additional compounds have been placed in holes in branches carefully selected the summer before, the holes 2 to 3 inches apart around the branch and carefully plugged with tree-seal: aluminum nitrate, aluminum ammonium sulphate, potassium chlorate, sodium molybdate, sodium selenate, strontium sulphate, sodium tungstate, uranium sulphate, and zirconium sulphate. None caused any benefit. Titanium potassium oxalate in aqueous solutions, 1.5 per cent and 3 per cent, sprayed onto grapevines May 15, 1934, caused no benefit. A 1 per cent zinc sulphate solution applied to adjacent vines at the same time caused striking improvement in 3 weeks.

Zinc phosphate and zinc carbonate are among the least soluble of zinc compounds. Four branches treated with zinc phosphate and as many treated with zinc carbonate, in both cases in holes closer around the branch and in larger quantities to the hole than we have used of any substance except zinc oxide, showed no improvement as compared with check branches on the same trees carefully chosen during the worst mottle-leaf season of the preceding summer. The same branches would certainly have been cured completely by treatment in fewer holes to the branch and with smaller quantities to the hole of zinc sulphate, zinc oxide, or powdered zinc, or by zinc pieces driven 2 to 3 to the inch around them.

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Progress on the Control of Citrus Chlorosis or Decline

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We reported last year that a widespread chlorosis or yellowing of plants in Arizona yielded to treatment with iron. A list of more than 20 different plants showing this condition was presented. Of these, various species of citrus are of most economic importance in Arizona.

In citrus, the disease is known by various names as "chlorosis", "decline", and "die-back", each descriptive of some symptom or condition displayed by affected trees. Strangely, young trees are rarely affected. The first symptoms are not often observed before the trees are 8 to 12 years old. The disease if present in trees of this age is likely to be manifested by mild chlorosis of typical pattern affecting some few leaves on the lower outside branches. As the trees become older more leaves are affected and the intensity of the chlorosis of each is increased to where the leaf color may be predominately yellow. Leaves on the entire outer and lower branches may become yellow. This stage of the disease is found on trees 16 to 20 years of age. Some lower limbs may be more severely affected than others. Contrarily, on old and badly diseased trees, it is the topmost parts which are most severely affected, the lower outside branches may be quite normal. In the top of such trees the leaves are very chlorotic. This is frequently followed by a necrosis and abscission, leaving the shoots bare. Frequently many of the shoots die and not infrequently the die-back includes large limbs.

The advancement of the disease is gradual and the decline of the trees induced by it is equally so. It is not often that affected trees die outright. More often, the owner becomes discouraged and removes them when efforts to correct the trouble have failed. This and the low productiveness of trees during the period of decline accounts for the loss occasioned by it. In addition, its occurrence in many older orchard trees has been a threat to the permanence of citrus groves generally in the State.

Because of the seriousness of the disease in citrus and of the economic loss occasioned by it, our efforts for the past season have been confined to studies of the condition in citrus.

During the past year some citrus tissue has been analyzed for iron and other elements. These analyses have not yet revealed a reduced iron content in affected tissue. It seems that affected trees which respond to iron contain as much iron as healthy green ones. If this is true, the condition is perhaps analagous to that reported by workers with other plants in which affected tissue has not been found to be deficient in iron.

Field experimentation during the past season has been directed toward two ends: (1) to find a satisfactory means of applying iron to the trees, and (2) to find means of rendering the iron held in the tree available to the growing tissue and in this way overcome the chlorosis. The following is a summary of treatments and results:

FIG. 1. Old citrus trees on the Yuma Mesa. Above—A Marsh Grapefruit tree: (left), as it appeared on Oct. 20, 1933, when it was treated by placing commercial ferrous sulfate in holes bored into the trunk; (right) the same tree on Aug. 25, 1934.

Below—Two chlorotic lemon trees which were in advanced stages of decline in the spring of 1934: (left) untreated; (right) treated with ferric citrate during April. Photographs taken Aug. 25, 1934.

1. Placing ferric citrate in holes bored in the tree trunks:—This treatment has produced the quickest and thus far the most permanent response of any treatment. Orange, grapefruit, and lemon trees have responded well to this treatment. Frequently they have completely recovered within a few weeks following the treatment. Improvement can be noted on rapidly growing trees in a few days. Trees treated by this method one year ago are still healthy.

2. Placing ferrous sulfate in holes bored in the tree trunks:—The results of this treatment, while very apparent, have not been so consistent or so permanent as those with ferric citrate.

3. Placing ferric tartrate in holes bored in the tree trunks:—The results here have shown less promise than in either of the above.

4. Soil applications of ferrous sulfate:—Twenty to 40 pounds of iron sulfate placed in holes 1½ inches in diameter and 2 feet deep around the drip of the tree has generally been followed by improvement of the tree. Such treatments made in January before the spring flush of growth were more effective than those made at other times. The same material when applied in a circular trench 1 to 2 feet from the trunk of the tree has been less effective.

5. Soil injections with solution of ferrous sulfate:—A 10 per cent solution of ferrous sulfate was injected into 40 to 50 holes about mature chlorotic orange trees by means of a power sprayer with soil injection rod and nozzle. This resulted in a response equal to but apparently no better than from the use of the dry material placed in holes. Sulfuric acid to make a 3 per cent solution when added to the above produced no additional effect. No improvement resulted from the injection of a 3 per cent sulfuric acid solution alone.

6. Soil applications of ferric oxide:—This material applied in the same manner as the ferrous sulfate has as yet given no response.

7. Application of sulfuric acid in irrigation water:—Sulfuric acid has been applied with the irrigation water to individual trees. It has been given to trees receiving no additional treatment and to others in combination with iron sulfate, iron oxide and ammonium sulfate. The application of acid was begun in April. From 1 quart to 1 gallon per tree has been applied at each irrigation through the summer. A total of as much as 10 gallons has been added to the water given a single tree. In no case has any effect been observed. When applied with the iron there has been no response that has not been obtained with the iron alone.

8. Shading:—Shades were constructed over two trees. The effects of the shade on chlorosis are as yet in doubt.

The continued response of citrus trees in advanced stage of decline leaves little doubt but that the specific cause of citrus decline in Arizona is in some way related to the metabolism of iron. Studies of the distribution and rôle of iron in citrus are being continued with the hope that from them more satisfactory and permanent methods of preventing or correcting the disease can be devised. The information gained to date is making it possible for growers to postpone the period of decline and correct it at least temporarily in trees already affected.

Chlorosis or decline is probably the most important physiological disease of citrus in Arizona. There are others which are similar in

that they appear also to arise from imperfections in mineral nutrition but in these the type of chlorotic pattern produced is quite distinct from that displayed by trees affected with decline. The so-called mottle leaf which yields to treatment with zinc is one. There is apparently a wide difference in the fundamental relationships of these two troubles for the mottle leaf is most abundant on very young trees whereas the decline is a cumulative condition seldom affecting young trees and becoming more severe as the trees become older. Other distinct types of chlorosis and abnormalities have come under observation during the past year. These have caused varying degrees of loss. While no studies have been made of them, it is suspicioned that they represent still other phases of mineral nutrition involving undesirable quantities or relations of ions or elements other than iron and zinc.

Further Notes on Pecan Filling and Maturity

By A. H. FINCH[1], *University of Arizona, Tucson, Ariz.*

THIS station previously reported (1) that certain phases of fruiting in the pecan might be related to the internal nutrition or composition of the tree as indicated by its condition of vegetativeness. It was suggested that best filling and most satisfactory maturity of the nuts accompanied a condition of low vegetativeness of the tree wherein yellow, autumnal colorations of the leaves appear during early fall. It was also suggested that a relatively high degree of vegetativeness seemed to favor blossoming, setting, and sizing of nuts.

During the past year efforts have been directed toward two ends: (1) to determine further if fruiting is related to vegetativeness of the trees, and (2) to learn means of controlling vegetativeness.

STUDIES ON THE RELATION OF VEGETATIVENESS TO FRUITING

In the spring of 1934 blossom counts were made on Burkett trees which had varied widely in greenness of foliage during the late summer of 1933 and which at that time had borne nuts varying widely in character of filling. The data obtained are shown in Table I.

The difference in blossoming percentage between high and low vegetative trees was outstanding. The percentage of pistillate blossoms which set nuts was obtained by tagging clusters on strong and weak shoots and recording the number of nuts present at intervals thru the season of dropping. This period of drop has been found to end about June 1 in the Yuma Valley.

TABLE I—FILLING OF NUTS IN 1933 AND BLOSSOMING IN 1934 AS RELATED TO VEGETATIVENESS OF THE TREES

Condition of Trees Fall of 1933	Nut Filling in 1933	Percentage Blossoming* in 1934
Highly vegetative.........	Poorly filled	30–45
Poorly vegetative.........	Well filled	6–18

*Percentage of 1934 shoots bearing pistillate blossoms.

The percentage of blossoms which set nuts on the poorly vegetative trees ranged from nothing on weak shoots to 12 per cent on strong ones and on highly vegetative trees from 24 to 66 on weak shoots and from 29 to 65 on strong ones. These trees were all in orchards under widely varying conditions of irrigation and culture.

Throughout the past summer, but particularly from early August to harvest, observations were made upon the development of nuts in the Yuma Valley on highly vegetative trees in a well-cared-for orchard and on poorly vegetative trees in a neglected one. The trees for study were selected as previously on the basis of greenness of foliage without thought as to culture or irrigation practice. Soil nitrate determinations made in 1933 indicated a content of 25 to 100 parts per

[1]The writer gratefully acknowledges the assistance of Mr. L. P. Hamilton, Jr. and Mr. C. W. Van Horn, students at the University, who made many of the soil nitrate and moisture determinations, and of Mr. J. F. Breazeale, of the Department of Agricultural Chemistry, who made the nitrogen and phosphorus analyses of the pecan tissue.

million in the highly vegetative grove and from 0 to 15 in the poorly vegetative one. No soil moisture or nitrate determinations were made in these groves in 1934 but it was judged that moisture was available at all times since there was no wilting of surface vegetation.

Up to the middle of August, the development of the nuts and seed coats appeared to be about equal on both types of trees. On August 19, it was noted that the liquid which had previously filled the seed coat was no longer present, leaving it empty except for a thin layer of jelly-like substance on the inner surface. This condition remained for only a few days. By August 26, it was noted that "filling" was occurring rapidly. The deposition of solid materials continued rapidly in nuts on the poorly vegetative trees for the ensuing 10 days or more and by September 10 the kernels on these trees were filled solidly but sugars probably continued to be deposited as nuts harvested then did not become well flavored.

Nut kernels from the highly vegetative trees were not so well filled in early September and even though filling continued to increase slowly up to about October 5 the nuts did not attain the well filled condition of those borne by the poorly vegetative trees. The specific gravity of nuts from the two types of trees is shown in Table II. In addition to being less well filled, the kernel of nuts from the highly vegetative trees was soft and lacked in oil, flavor and keeping quality.

If the true course of filling has been indicated in these observations then the storage of carbohydrate reserves in the tree during the summer months is of especial importance for it is unlikely that the rapid deposition in the nuts of large quantities of storage materials having such high calorific value could be accomplished from concurrently elaborated photosynthetic products. It is more probable that the food materials moved into the nuts so rapidly in late summer arise chiefly from those formed and stored elsewhere earlier in the summer. It may be that the higher nitrogen content of the highly vegetative trees (Table II) is unfavorable to the storage of carbohydrates for later filling. On such trees are found the largest leaves; accordingly, if concurrent elaborated foods alone are important in filling the best filled nuts might be expected on these trees. This is clearly not the case. It is hoped that in another season studies of the physiology of filling can be undertaken.

Beginning on September 24, and following at weekly intervals, leaves, nuts, and shucks were collected from the poorly and highly vegetative trees on which the course of filling was being studied. The tissue collected was at once placed in weighed, air tight containers and taken to the laboratory where the filled containers were again weighed, covers removed, and the material dried at 80 degrees C for determination of moisture content. Nitrogen and phosphorus analyses were made on the same material. The data obtained are given in Table II. It is believed that they suggest an inverse relation between nitrogen and moisture in the plant tissue and filling of the nuts. There is no indication that poor filling is associated with a deficiency of phosphorous. The nuts from the poorly vegetative trees ripened earlier, threshed more easily and the shucks separated more readily from the shell than was the case in the highly vegetative trees. Pre-harvest germination was 10 and 58 per cent, respectively.

TABLE II—Per cent Moisture, Nitrogen, and Phosphorus in Leaves, Shucks, and Nuts; and Specific Gravity of Nuts from (1) Poorly Vegetative Trees and (2) Highly Vegetative Trees (Burkett Variety). Collected in Yuma Valley, 1934*

Date Sampled	Constituents	Leaves 1	Leaves 2	Shucks 1	Shucks 2	Nuts 1	Nuts 2	Sp. Grav. of Nuts 1	Sp. Grav. of Nuts 2
Sept. 24	H_2O	—	—	—	—	—	—		
	N	1.67	1.80	1.10	1.61				
	P_2O_5	.27	.22	.26	.67				
Oct. 1...	H_2O	53.2	54.2	77.6	82.3	33.6	33.4		
	N	1.68	1.70	.87	1.48	1.20	1.37	.753	.625
	P_2O_5	.36	.26	.22	.22	.38	.40		
Oct. 8...	H_2O	53.7	53.7	78.8	83.9	27.8	31.7		
	N	1.75	1.72	.72	1.41	1.31	1.49	.725	.627
	P_2O_5	.20	.22	.12	.34	.35	.42		
Oct. 15..	H_2O	52.4	53.2	79.7	83.3	24.5	31.3		
	N	1.78	1.71	.97	1.18	1.36	1.51	.732	.634
	P_2O_5	.22	.22	.09	.16	.35	.39		

*Per cent nitrogen and phosphorus, and specific gravity based on air dry weight.

Studies on Control of Vegetativeness

In March, 1934, eight 8-year-old Burkett trees were selected in an orchard of the Yuma Valley. These trees were located so as to fall into four separate plots each consisting of two adjacent trees. An irrigation border was placed around each plot. Beginning March 14 treatments were initiated which were designed to influence the amount of soil nitrates and, it was hoped, the vegetativeness of the trees. These consisted of fertilization with sugar (cerelose) to depress nitrates and with ammonium sulfate to increase nitrates along with other treatments as indicated in the following schedule. The treatments given Plot A were designed to reduce greenness of the trees in early summer and increase it in late summer. B was to be held highly vegetative and C poorly vegetative all summer. D was to be highly vegetative in early summer and poorly vegetative in late summer.

TABLE III—Schedule of Procedure Designed to Influence Vegetativeness

Date	Plot A	Plot B	Plot C	Plot D
	Sugar per tree:	$(NH_4)_2SO_4$ per tree:	Same as A	Same as B
Mch. 14	10 pounds	10 pounds		
Apr. 21	20 pounds	15 pounds		
May 22	15 pounds	10 pounds		
June 12	25 pounds	5 pounds		
July 23	30 pounds	5 pounds		
Aug. 6	10 pounds $(NH_4)_2SO_4$ and ½ ton manure per tree. Usual irrigation schedule maintained through late summer and fall.		50 pounds sugar per tree, land plowed deeply, cutting surface roots. *Andropogon sorghum* planted. Irrigations withheld in late summer.	

Soil samples were taken at two locations in each plot at intervals throughout the summer. Each location was sampled at the 1st and 2nd foot separately and the 3rd and 4th feet combined. Soil moisture was determined by drying at 110 degrees C. Nitrates were measured colorimetrically by the phenoldisulfonic acid method. The data averaged for all depths are shown in Fig. 1. Nitrates tended to be highest

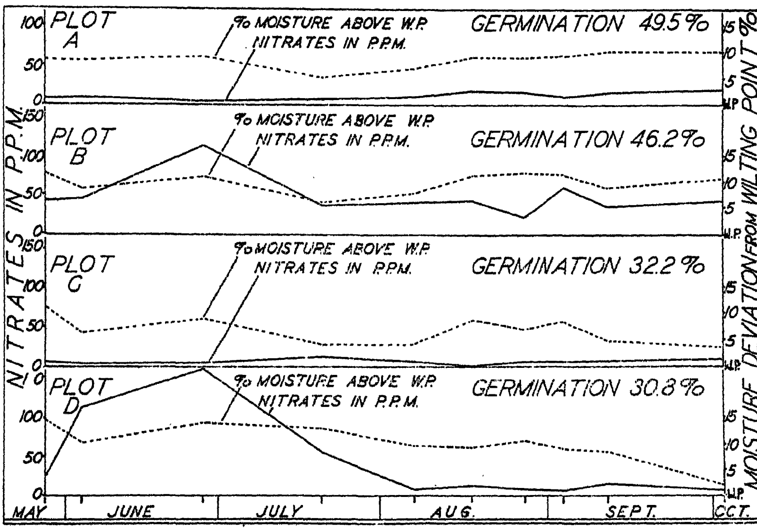

FIG. 1. Per cent of soil moisture above the wilting point and parts per million of soil nitrates in the different plots. Where moisture and nitrates were lowest in the late summer the trees were a less intense green and pre-harvest germination was reduced.

in the surface foot but were present in relative abundance in the lower depths. Soil moisture was usually lowest in the first foot but was in no case below the wilting point.

It was apparent by October 1, that the leaves on the trees in Plots C and D were not as intense a green as those of Plots A and B. However, they were much greener and displayed less intense symptoms of nitrogen starvation than did the trees previously mentioned as growing in a neglected orchard. Similarly the trees given nitrogen fertilization all season (Plot B) were not as highly vegetative as those growing in the well cared for orchard.

Clearly, the treatments given this season did not produce wide extremes of vegetativeness. There may be several reasons for this. For one, nitrates were only depressed and not completely eliminated. Only nitrates were measured. The high vegetativeness of some trees growing with certain legume cover crops and relatively low soil nitrates suggests that possibly other forms of soil nitrogen may be important in the nutrition of the pecan. It is known that the irrigation water (Colorado River) carries appreciable nitrates. Perhaps, to reduce vegetativeness of the trees it may be necessary to withhold

water more extensively than was done this year. Reserve nitrogen in the trees may be a further important factor in determining their vegetativeness in the late summer.

Without having produced the widest extremes in vegetativeness, some important differences were noted in percentage of pre-harvest germination. Nuts from Plots A and B, where moisture and nitrates were maintained high in the late summer, had 49.5 and 46.2 percentage germination, respectively. Plots C and D where moisture was depressed and other treatments given to reduce growth and vegetativeness in late summer had 30.8 and 32.2 per cent of pre-harvest germination. Filling was not greatly different between plots. It was, however, typical of the degree of vegetativeness, nuts being better filled than in more highly vegetative trees and not so well filled as in poorly vegetative trees.

A summary of this evidence obtained in 1934 again suggests that some problems of filling, pre-harvest germination and maturity are associated with or induced by a too high degree of vegetativeness of the tree. For best filling it appears that growth of the trees must be checked during the early summer to provide conditions for carbohydrate storage during the summer months. On the other hand, most blossoming seems to be associated with a relatively high degree of vegetativeness.

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Polishing, Bleaching and Dyeing the Pecan

By L. M. Ware, *Alabama Agricultural Experiment Station, Auburn, Ala.*

Abstract

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Effect of Nut Thinning on Size, Degree of Filling, and Annual Yields of Pecans

By H. L. Crane, Max B. Hardy, N. H. Loomis, and F. N. Dodge, *U. S. Department of Agriculture, Albany, Ga.*

STATISTICS on the annual yields in the various pecan growing districts show the almost universal tendency of pecan trees to bear more or less irregular crops from year to year. Individual tree yield records indicate that this irregularity in yields cannot be called either biennial or alternate bearing. Tree records show a range in fruiting in which trees may bear approximately equal annual crops, or a heavy crop one year and a light one the following year, or a crop one year followed by one or more years of absolutely no crop. The pistillate flowers of the pecan are borne in an indeterminate terminal inflorescence on the current season's wood, similar to the brambles, and there is nothing in this type of fruiting habit to explain these irregularities in crop production. This is borne out by the fact that trees of all varieties have been known to bear annual crops under some conditions. Without doubt, the controlling factor is the nutritional condition of the tree, which is altered materially by cultural practices, seasonal conditions, and the previous performance of the tree. However, even in well cared for orchards where the nutritional condition of the trees is apparently at a high level, trees of most varieties usually bear only a light crop the year following a heavy crop. This is especially true of such highly prolific varieties as Moore, Teche, Curtis, and Nelson. The size and degree of filling of the nuts may be, at the same time, adversely affected the year of the heavy crop.

It was noted that all trees did not bear their heavy crop the same year, which further indicated that the irregular yields were caused by the nutritional condition of the individual tree. Thinning the fruits on other fruit trees appears to be one of the most promising means of breaking up their biennial or alternate bearing habits, by reducing the heavy crop to a point where sufficient food reserves can be maintained for approximately uniform fruit bud initiation and set each year. The nutritional condition in the pecan is apparently comparable to that of other fruits and because of the difference in time of fruit bud initiation, it appeared likely that thinning the pecan would be even more effective in altering the yield and quality of fruit produced.

Studies on the effect of thinning the nuts set have been carried on by the authors during 1933 and 1934, using 13-year-old trees of the Moore variety located in an orchard about 3 miles from Albany, Georgia. Even with the excellent care which the comparatively young trees in this orchard have received, the yields in the past gave evidence that biennial bearing was firmly established. The nuts harvested were usually fairly well filled, but the size was smaller than desirable.

For use in 1933 a block of 30 trees was selected as representative of the condition described, although no previous individual tree yield records were available as a basis for the selection. Twelve trees carrying a heavy crop were selected for the detailed study of thinning. The leaves and nuts were counted on several large limbs of each of

these trees and the number of leaves per nut was taken as representative of the whole tree. The counts varied from 3.5 to 9.8 leaves per nut. The entire crop of six of these trees was thinned, by removing 33 per cent of the nuts on some, and 50 per cent on the others. The remaining six trees were left as checks. No thinning was done in this block in 1934, but certain individual tree records were obtained on all thirty trees.

The thinning work in 1934 was carried on with a block of 54 trees in another part of the same orchard. The number of leaves per nut, ranging from 3.32 to 11.19, as determined by the method used in 1933, was obtained on 20 of these trees, nine of which were finally selected for thinning. The degrees of thinning used were the same as in 1933.

The actual thinning of the nuts was done on August 10 and 11, 1933, and on August 21 and 22, 1934. In both years the shells of the nuts had started to harden when the thinning was done, and while it was realized that it was too late to expect much if any influence of thinning on the size of nuts, yet the summer drouths, which were more severe and extended in 1934 than in 1933, made it inadvisable to thin before they were broken.

The 2-years' data on the trees in the 1933 thinning block show some interesting evidence of the effects of thinning, although these data cannot be considered as a basis for final conclusions. Every tree, except one of the unthinned trees and some of those which were thinned in 1933, exhibited the biennial bearing habit in 1934. The average yield per tree of the six unthinned trees in the "on year" was 34.6 pounds, while in the "off year" it was 9.8 pounds, with five of the trees having their "on year" in 1933 and the sixth in 1934. The average yield per tree on the six thinned trees was 37.0 pounds in the "on year", and 22.1 pounds in the "off year". The thinning was necessarily done in the "on year." Keeping this in mind, and also that the thinning was done on trees with an original number of leaves per nut comparable in range to the unthinned trees, it is of interest to note that four of the thinned trees produced a greater yield in 1934 than in 1933, the year they were thinned.

The percentage of bloom the year following a heavy crop is of outstanding importance because a good bloom is a necessity if a good crop is to be expected again. The effect of thinning on the percentage of bloom the following year was somewhat dependent on the original number of leaves per nut and on the degree of thinning. Of the six unthinned record trees, the one having 9.8 leaves per nut came back in 1934 with more than 40 per cent of the shoots blooming, and this was the only tree of the six which produced as large a crop in 1934 as in 1933. Of the six thinned trees, none of which originally had more than 6.1 leaves per nut, five were thinned to 8.7 or more leaves per nut, and four of these showed 40 per cent or more of the shoots blooming in 1934. These four were the same trees which in 1934 produced a crop equal to or greater than their 1933 crop. It appears that under conditions of culture, moisture, tree age, and previous performance similar to those of this experiment, 8 to 10 leaves per nut, either before or after thinning, is the optimum leaf area assuring

the accumulation of enough reserves in the tree to provide sufficient bloom the following year for approximately uniform yearly crops.

A relatively early and severe summer drouth in both years cut down the size of the nuts on the trees used in this experiment, and thinning after the drouths were broken by good rains in August was not expected to materially affect the size of the nuts, and it did not. Following these August rains, September and October were much drier than normal, but the degree of filling of the nuts was fair, although below the usual standard for this orchard.

The degree of filling of the nuts was found to be dependent, to a large extent, on the number of leaves per nut. The data on both the 1933 and 1934 crops from this block showed that as the number of leaves per nut increased, the degree of filling of the nuts, as determined by the number of nuts per pound for each size, also increased. Comparisons between the thinned and unthinned trees, after first classifying them into three groups, on the basis of their original number of leaves per nut, namely, (1) 4.5 or less leaves per nut, (2) 4.6 to 9.0 leaves per nut, and (3) 9.1 or more leaves per nut, also show that increasing the number of leaves per nut slightly increases the degree of filling of the nuts.

According to these data, it might be expected that in a season of normal growing conditions, earlier thinning would cause a greater increase in the size and the degree of filling of the nuts, as well as provide sufficient food reserves for optimum blossoming the following year. Under such conditions it would seem possible, also, that a smaller number of leaves per nut would be as effective as the number indicated by the data obtained. However, nuts of large size require more food to completely fill them than do nuts of small size and thus, within any variety, large nut size appears antagonistic to a high degree of filling. It is also a fact that a severe drouth may have much more serious effects on a pecan tree than are immediately apparent. During a dry period pecan leaflets and leaves will usually drop, with no previous signs of wilting, and the remaining leaf area, while almost normal in appearance, is doubtless lowered in efficiency. As a consequence, the exact relationships existing cannot be determined without further study.

The results obtained in the 1934 thinning block are in general similar to the results obtained in 1933 on the trees thinned that year. Regardless of thinning, the degree of filling of the nuts was slightly increased as the number of leaves per nut increased. However, nuts from thinned trees were no better filled than nuts from unthinned trees in any of the three leaf-per-nut classes. The nuts harvested in 1934 tended to be smaller than those harvested in 1933, and were also somewhat better filled. The smaller size was due most probably to the more severe and extended drouth in the summer, and the high degree of filling of the nuts indicates that the number of leaves per nut was in no case particularly limiting. It should be pointed out that there is apparently a limit in the degree of filling for a nut of any particular size, beyond which filling cannot go. From the data obtained, completely filled nuts of the Moore variety will probably run about as follows: (1) Diameter 10/16-inch, 140 nuts per pound;

(2) 11/16-inch, 102 nuts; (3) 12/16-inch, 86 nuts; (4) 13/16-inch, 73 nuts; and (5) 14/16-inch, 63 nuts. With poorer filling, number of nuts per pound in the various size classes will, of course, increase.

The small number of trees used in this experiment makes it impossible yet to set any limitations to the influence of the factors involved. Aside from all external factors, individual tree variation is apparently of considerable importance. Because of these variations it is difficult to establish accurately the effective degree of thinning applied to any one tree, and the need for using a larger number of trees than have as yet been used is thus emphasized.

While thinning cannot as yet be recommended as a commercial practice, yet the limited data obtained indicate that it may be expected to increase not only the size and degree of filling of the nuts of any one crop and the bloom the following year, but also over a period of years it may be expected to increase the annual yield per tree by more nearly maintaining an optimum nutritional condition in the tree at all times.

Growth and Yield of Pecan Trees, as Affected by Thinning the Stand of Trees and Other Orchard Practices

By H. L. Crane, Max B. Hardy, N. H. Loomis, and F. N. Dodge, *U. S. Department of Agriculture, Albany, Ga.*

CROWDING of pecan trees in an orchard with all attendant difficulties apparently begins much earlier than was expected. Recently Woodroof and Woodroof (1) have shown that the spread of the root system of a pecan tree is about twice that of the branches. Numerous observations made by the writers and others indicate that the root system of a pecan tree tends to exhaust the soil of moisture and fertility for a distance fully twice as great as the spread of the branches. In regions similar to that around Albany, Georgia, where the mean annual rainfall is approximately 50 inches, but where drouth may be expected either in the summer when the nuts are growing in size or in the fall when the kernel is being formed, and where irrigation is not practiced, the spacing of the trees on the soil is now considered an important factor affecting production.

Methods and Materials Used

In the spring of 1932 a portion of a 24-year-old Stuart orchard, located on Orangeburg soil near DeWitt, Georgia, and planted 20 trees to the acre, was divided into four blocks containing from 10 to 14 trees each, surrounded by guard trees. The soil management, spraying, and pruning, as well as other orchard practices, have been uniform in all plots except as noted below:

Block A[1]:—Check. Trees 46 feet 8 inches on the square.

Block B[1]:—30 pounds of commercial sulphate of ammonia per tree; applied ½ the middle of March, and ½ the last of May. Trees 46 feet 8 inches on the square.

Block C[1]:—Heavily pruned. At the beginning of the experiment the tree tops were cut back to approximately half their size; with subsequent light, or corrective pruning, and some heading back of long branches. Trees 46 feet 8 inches on the square.

Block D[1]:—Trees thinned to 10 per acre, or 93 feet 4 inches apart on the quincunx system.

At the beginning of this experiment the trees were quite uniform; averaged 120.5 square inches in cross-sectional area of the tree trunks, and were in a uniformly low state of vigor. Data were taken on the length of the shoots of the past season on six or more trees in each block. These data show that the mean length of the shoots in the different plots varied only from 1.53 to 1.56 inches, the longest shoots being 8 inches or less in length.

Due to the unprecedented drouth occurring in the fall of 1931 when

[1]The trees of Blocks A, C, and D have received a uniform fertilization with 10 pounds of ammonium sulphate applied the last of March in the years of 1933 and 1934. Guard trees received the same fertilizer treatment as those of adjacent blocks.

the crop of nuts was maturing, the trees in this experiment were so severely injured through killing of the fibrous roots, exhaustion of reserves, and injury to the branches, that foliation in the spring of 1932 was delayed until around June 1, or about 2 weeks after some heavy, soaking rains fell. Tree growth during the season of 1932 was therefore abnormal. In 1933 the month of May was quite dry, and the set and size of the nuts was reduced; July and August were normal, but the fall was the driest on record. The early part of the 1934 season was favorable for growth of the trees but late summer and fall were extremely dry, and the nuts produced were generally poorly filled.

Growth Response

The growth response of the trees has been measured by the annual gain in cross-sectional area of the tree trunks, measured at a marked point, and by the length of the current season's growth of 500 or more shoots per tree. In Table I is given the average gain in cross-sectional area of the tree trunks for each of the four blocks:

TABLE I—Average Gain in Cross-sectional Area of the Tree Trunks

Block and Treatment	Average Gain in Cross-sectional Area (Sq. In.)		
	Season		Two-year Ave.
	1932	1933	
A. Check	$3.47 \pm .254$	$3.28 \pm .316$	$3.38 \pm .198$
B. 30 pounds $(NH_4)_2SO_4$	$2.81 \pm .220$	$4.69 \pm .253$	$3.75 \pm .214$
C. Heavily pruned	$2.03 \pm .182$	$3.14 \pm .093$	$2.59 \pm .149$
D. Thinned to 93 ft. 4 in. quincunx	$3.51 \pm .258$	$6.22 \pm .385$	$4.87 \pm .338$

These data show that in Block C heavy pruning of the trees at the beginning of the experiment significantly reduced the gain in cross-sectional area of the tree trunks the first season following the pruning, and even the second year the gain was still somewhat smaller than that made by the check trees, but not significantly so.

The application of 30 pounds of sulphate of ammonia per tree in Block B resulted in smaller gains in cross-sectional area of the tree trunks the first year, but the second year the gains were significantly larger than on the check trees. Thinning the trees to 93 feet 4 inches apart on the quincunx system resulted in a highly significant average gain of 4.87 square inches for the 2-year period; by far the largest gain made by any of the blocks. It is interesting to note that these thinned trees made about the same growth of tree trunks as the check trees the first year, but the second growing season they almost doubled the growth of the check trees.

Data for the length of shoot growth are not given, since these data follow, in general, the same tendencies as those for cross-sectional area. It should be pointed out that shoot growth of the trees in Block C, which was heavily pruned, averaged 4.93 and 5.35 inches for the first and second year following pruning, while the shoots on the check trees averaged only 1.52 and 2.42 inches. Applications of ammonium sulphate in Block B, and the thinning of the trees in Block D had

some effect on the length of the shoots, but to a very much less degree than was true of the gain in area of the tree trunks.

An outstanding response of the thinned trees in Block D has been the drooping of the lower limbs of the trees and a tendency of the tree tops to spread out, with the production of new wood and a much greater leaf area well toward the inside or center of the trees. The trees of Block D, as a result of the greater spacing, now have wood on the lower limbs which should fruit next season, while the crowded trees of Blocks A and B have practically all of the fruiting wood in the upper half of the tree tops.

Fruiting Response

In Table II are given the data for the average yield of nuts, in pounds per tree, for the years 1933 and 1934. Due to the extreme drouth of 1931, the trees in this experiment were so severely injured and devitalized that there was no bloom in any of the blocks in 1932.

TABLE II—Average Yield of Nuts per Tree

Block and Treatment	Average Yield per Tree (Pounds)		
	Season		Two-year Ave.
	1933	1934	
A. Check	9.2 ± 1.00	$4.0 \pm .43$	6.59
B. 30 pounds $(NH_4)_2SO_4$	16.3 ± 1.38	$2.2 \pm .35$	9.25
C. Heavily pruned	0.0	$.9 \pm .17$	.47
D. Thinned to 93 ft. 4 in. quincunx	$10.0 \pm .20$	8.0 ± 1.06	9.00

These data show that in 1933 the trees of Block B yielded significantly more nuts than the trees of Black A, while in 1934 the average yield of the two plots was reversed. This was probably due to the combination of the larger crop of nuts produced by the trees of Block B in 1933 and to the extreme drouth occurring the same fall, which prevented the accumulation of reserves in the trees sufficient for the blossoming and set of as large a crop of nuts as was produced by the check trees of Block A, which did not bear so many nuts in 1933. The important fact to be brought out here is that although heavy applications of sulphate of ammonia have been applied to the trees of Block B, the average yield over the 2-year period has been but little more than that of the trees of the check Block A. Not only has the application of sulphate of ammonia not paid, but through the stimulation in growth and leaf area of the trees resulting from its use, the trees have suffered more from drouth than those of Black A.

The effects of heavy pruning on the yield of the trees was quite unexpected. As has already been pointed out, the trees of Block C made much better shoot growth in 1932 than those of any other block, but the severe pruning, together with the drouth, probably prevented the accumulation of sufficient food reserves to cause fruit bud initiation. As a result, in 1933 there were no nuts on any of the trees in this block, and in 1934 the yield was but .9 pound per tree.

Thinning the stand of trees in Block D has resulted, over the 2-year period, in as large yields per tree, though not per acre, as any of the treatments under consideration, and in the most uniform production of nuts. It should be pointed out that in 1934 the yield of the thinned trees was almost four times that of the trees which were fertilized with sulphate of ammonia, although there was little or no difference in the average yield per tree of the two plots for the 2-year period.

The nuts from this experiment were graded into sizes varying 1/16-inch in diameter, and the number of nuts per pound was determined for each size. These data for the crop year of 1934 are given in Table III. They show that the trees of Block B, which were fertilized with sulphate of ammonia, produced the highest percentage of small nuts and the lowest percentage of large nuts of any of the trees in this experiment, thus plainly showing the effects of the drouth, and that it was more severe on the trees on which the growth and leaf area had been stimulated. There was little or no difference in the number per pound of the nuts from the check trees of Block A or the fertilized trees of Block B. The heavily pruned trees of Block C produced the highest percentage of large nuts of any of the blocks in this experiment, but they were not as well filled as those from Block D, where there were only half as many trees per acre. Block D, although not producing as high a percentage of large nuts as Block C, had the best filled nuts of any of the blocks.

TABLE III—PERCENTAGE[1] OF TOTAL 1934 CROP FALLING IN VARIOUS SIZES, AND THE NUMBER OF NUTS PER POUND IN EACH SIZE

Block and Treatment		Nuts of Indicated Diameter (In.)				
		12/16 and Smaller	13/16	14/16	15/16	16/16 and Up
A. Check	Per cent	1.5	11.0	59.7	22.3	.5
	No. per pound	90	79	67	59	50
B. 30 pounds $(NH_4)_2SO_4$	Per cent	6.7	25.0	53.6	14.3	.4
	No. per pound	87	76	67	57	50
C. Heavily pruned	Per cent	.0	1.3	16.0	70.2	12.5
	No. per pound	—	73	67	56	49
D. Thinned to 93 ft. 4 in. quincunx	Per cent	.1	2.7	35.5	56.1	5.5
	No. per pound	87	73	63	54	45

[1]Data for 1933 not given, as they show the same tendencies.

DISCUSSION

The dry weather which has prevailed since this experiment was started has greatly interfered with the response of the trees to the treatment given. In view of the fact that a majority of the producing seasons may be expected to be dry, it is believed that the results set forth are indicative of those which growers may expect from thinning the stand of pecan trees, as compared to pruning the trees or fertiliz-

ing them, in order to stimulate production. Of the treatments used in this experiment, thinning the stand of trees is the only one that shows positive commercial possibilities. It is true that the yield in 1933 and the average yield for the 2-year period, on an acre basis, were materially reduced by removing half of the trees, as compared to that of the nitrogen-fertilized trees or even the checks, but it should be pointed out that in 1934 the acre yield of the thinned trees was equal to that of the checks, and about twice that of Block B. Moreover, the increased commercial value of the larger sized and much better filled nuts produced over the 2-year period by the thinned trees has partially, if not completely, offset the value of the larger yield, on an acre basis, of the check trees. Furthermore, although the increased yield of nuts by the fertilized trees is significant, it has not been great enough to pay for the cost of the fertilizer used. Observations made by the writers in other orchards in which the stand of trees has been thinned, lead to the conclusion that removing fully half of the trees in crowded pecan orchards, together with good orchard culture, is the most satisfactory way of restoring productivity to the remaining trees.

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Effect of Bagging on the Drop of Pecan Clusters

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THE extremely heavy loss of pecan nuts between the time of bloom and harvest has been of great concern to all growers. In one orchard which has been well cared for, and for which the writers have records, the loss, exclusive of blossom drop, has been from 68.0 to 97.6 per cent of the entire crop during the 5-year period 1930 to 1934, inclusive. Woodroof, Woodroof, and Bailey (5) find that there are three periods of drop in the pecan—that is, (1) "first drop," or blossom drop occurring at pollination, when up to 50 or more per cent of the blossoms may drop; (2) "May drop," which occurs 10 to 20 days after pollination; and (3) "summer drop," beginning after the May drop and continuing until the shell of the nuts has become hard, or about September 1. The blossom drop has been shown by Isbell (3), and Finch and Crane (2) to be negatively correlated with the vigor of the blossoming shoots. The time and extent of the May and summer drops are known to vary from season to season. Little is known of the primary cause, or causes, of this heavy drop which occurs during the growth of the nuts and reduces the crop to such an extent that in some years it is practically a total loss.

Materials and Methods

To determine the extent of the drop of nuts due to physiological causes after the so-called May drop, experiments were initiated in late May, 1934, in five different Schley orchards around Albany, Georgia. The trees in these orchards varied in age from 12 to 30 years, or more. The cultural conditions varied from the application of the best practices known to a condition with the trees under sod culture with no additional care. Four of the orchards were sprayed to control pecan scab and leaf diseases, while one orchard received no spray during the season.

In an attempt to eliminate injury to the nuts by insects and diseases, they were covered with bags. Cellophane bags were selected because they were light in weight, transparent, and had been found to be satisfactory for use in pollination control (4). The nuts, ranging in number from 1 to 6 per cluster, were bagged during the last 2 weeks in May, or about 4 weeks after the first appearance of pistillate flowers. This allowed time for pollination of the flowers and for blossom drop to take place. The bags used were made of 4-inch sections of cellophane frankfurter casings 1⅛ inches in diameter. All bags were slipped over the nut clusters and tied over cotton batting or absorbent cotton wrapped around the stem below the nuts. Using large branches, every alternate cluster was bagged in this manner, the remaining clusters being considered as checks. All clusters were labeled and the number of nuts counted and recorded at the time the bags were put on. A total of 5100 clusters on 28 trees were prepared for use in this manner.

The small bags were left on the clusters from 4 to 6 weeks, when they were replaced with 4 x 2¾ x 9-inch bags made from No. 300

moisture-proof and plain transparent cellophane. The plain transparent cellophane bags were very similar to the ones made from the frankfurter casings. Moisture-proof bags were used in one orchard, and plain transparent bags in four orchards.

Records of the number of nuts remaining in each cluster were taken at two-week intervals until harvest.

Results

Four weeks after the nut clusters had been bagged a very heavy drop of all nuts in the bagged clusters had occurred, without a parallel drop in the check clusters. On examination, numerous egg-laying punctures and eggs of the myriad fly (species undetermined) were found at the point of attachment of the nut and the stem, and also on the nodes and internodes. Knowing that feeding punctures made by the stink bug will cause immature nuts to drop (1), it was thought that there might be some association between the punctures made by the myriad flies, or their eggs, and the drop of nuts. Furthermore, when the small bags were replaced by the large bags, it was observed that comparatively large quantities of moisture collected overnight within the bags made of moisture-proof cellophane but did not collect to such an extent in the bags of the plain type. It appeared possible that this alteration in humidity, and possibly also in temperature, was alone responsible for the nut drop.

These observations led to another experiment in which the two types of large cellophane bags were used in conjunction with two types of mechanical injury. The stems of certain clusters, or the point of attachment of the nuts to the cluster stem, were punctured by a fine needle, simulating egg-laying punctures. A part of these clusters was bagged and others left unbagged, with suitable checks.

This series of treatments, replicated 57 times and including 399 clusters on a single tree, was set up on June 26. The data show that the needle punctures had no effect on the dropping of nuts, regardless of the position or number of punctures made. However, enclosing the clusters in moisture-proof cellophane bags caused approximately 95 per cent of the nuts to drop within 13 days after they were bagged. Concurrently, clusters enclosed in plain transparent bags dropped 26.6 per cent of the nuts, as compared with 20.3 per cent drop of the checks.

It has been observed by the writers that Schley nuts sometimes split open when the developing kernel is in the "watery stage." This causes them to drop within a few days. This condition occurs only after a period of drouth followed by heavy rains, and has resulted in some instances in a heavy drop of nuts. Still other observations made on dropped nuts have shown internal discolored areas which appeared to be ruptured tissues. These observations, together with the results secured from enclosing the clusters in moisture-proof cellophane bags, led to the theory that this type of bag reduced transpiration and increased the internal pressure of the nuts to such an extent as to cause a similar rupture of certain tissues, and subsequent drop.

To test this theory, another experiment was set up on August 8 and 9. At that time the nuts had attained approximately full size and the

shells had begun to harden. For this work two groups of two trees each were used. These trees were 7 years old and very strong and vigorous, and were growing on an Orangeburg sandy loam soil. The two trees in one group were each supplied with 2 to 3 acre inches of water every third day, by irrigation in a basin of approximately 40 feet in diameter. The other group received no water other than the rainfall, which totaled 6.8 inches from August 7 to September 28.

The two types of cellophane bags, and also manila bags were put on the clusters in rotation, with suitable checks, and replicated from 60 to 70 times on each group of trees. A total of 527 nut clusters was included in this experiment. These data show that all three types of bags reduced the percentage of the clusters that dropped all their nuts. This was apparently due to protection of the nuts against subsequent injury caused by stink bugs and infestation by the larvae of the shuckworm, as the heavy drop of the check clusters was largely due to the injury caused by these insects. At the time the clusters were bagged a certain percentage of the nuts were infested with shuckworm larvae or had eggs deposited on them, neither of which could be seen. This infestation probably accounts for most of the drop which occurred under the manila bags, and probably represents the portion of the clusters under cellophane bags which dropped from this cause.

The data show that the percentage of the clusters in the manila bags which dropped was much smaller than the percentage in either of the two types of cellophane bags. Furthermore, in the moisture-proof cellophane bags the drop of clusters was again significantly higher than in the plain bags. It appears that the additional water supplied to the trees by irrigation had no effect on the dropping of clusters. In no case was there evidence of the rupture of any tissue of the nuts.

To determine if the various kinds of bags had any effect on the nuts harvested, certain physical measurements were made. Both types of cellophane bags significantly reduced the average size and weight of the nuts as compared to the checks. The nuts covered by the moisture-proof bags were smaller and weighed less than those enclosed in the plain cellophane bags. On the other hand the nuts enclosed in the manila bags were somewhat larger and weighed significantly more than those of the check clusters. The effect of the manila bags was most probably due to the protection of the nuts against injury caused by the larvae of the shuckworm, as practically 100 per cent of the unprotected nuts was infested at harvest. Enclosing the nuts in any of the types of bags significantly increased their specific gravity, as compared to the checks. This was most probably due to a reduction in the damage caused by the larvae of the shuckworm. The nuts enclosed in the manila bags had the highest specific gravity of all. Both types of cellophane bags reduced the specific gravity of the nuts as compared to those enclosed in manila bags. In this respect the moisture-proof bags were more injurious than the plain transparent ones. Maturity of the nuts, as indicated by the opening of the shucks, was delayed by the cellophane bags.

While these experiments with the various types of bags were being carried on, records of the drop were continued in the five orchards in which the original work was started. In order to illustrate the time

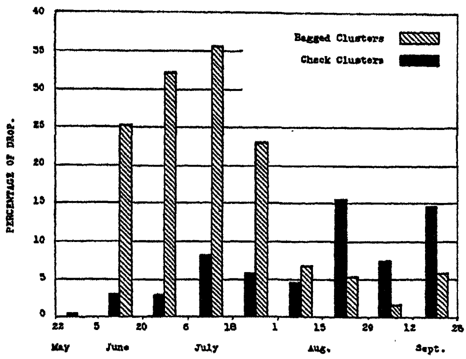

FIG. 1. Drop of pecan clusters in percentage of the total number recorded at the previous date.

and extent of the drop of check clusters as compared to that occurring under plain transparent bags, data are given for only one orchard. The drop of clusters, in percentage of the total number recorded at the previous date, is shown in Fig. 1. This shows a heavy drop of bagged clusters, which started the second period and continued through the fifth period, or up to August 1. The maximum drop of the check clusters occurred about the seventh period, or after the middle of August and about 6 weeks later than the period of maximum drop of the bagged clusters. In general, the time and extent of these periods of drop were similar in the different orchards.

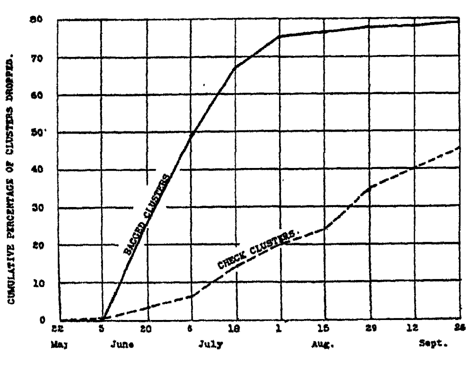

FIG. 2. Cumulative percentage of the pecan clusters dropped from May 22 to September 26, 1934.

In Fig. 2 the data are shown as the cumulative percentages of the clusters dropped from May 22 to September 26, 1934. Pistillate flowers appear at Albany, Georgia, about the last of April, and in no case has the heavy drop occurring prior to May 22 been included in the data. These data show a cumulative drop of 45.5 per cent of the check clusters, and 79.7 per cent of the bagged clusters. The drop of check clusters was fairly large and uniform during the entire season, with the greatest rate of drop occurring after August 15, or during the seventh period. This was true of the drop in the other orchards studied.

DISCUSSION AND SUMMARY

It has been shown that a large increase in the drop of nut clusters occurred following bagging with cellophane bags, and that the extent of this increased drop varied according to the type of bag and time of

enclosing the clusters. The evidence indicates that the nuts are most susceptible to injury from external influences during the period from about June 1 to September 1, when they are in the watery stage, and that these external factors are most injurious when they alter the environment most rapidly.

At this time it is not known why the cellophane bags caused the nuts to drop. It has been mentioned that relatively large amounts of water collected in the water-proof cellophane bags shortly after they were put on, indicating a saturated atmosphere. It is interesting to note in this connection, that growers hold the idea that heavy rains and high humidity at certain stages in the development of the nuts cause them to drop.

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Fruit Thinning and Biennial Bearing on Individual Main Leaders of Yellow Newtown Apples

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THIS report deals with further studies on the effect of fruit thinning in breaking the biennial bearing habit of Yellow Newtown apple trees. The experimental methods were essentially the same as those given in a paper before this society last year (2) in which individual main tree leaders were selected for detailed spur performance studies. It was observed that one or two main leaders on biennial bearing Yellow Newtown trees may show entirely different fruiting characteristics from the remaining portions of the tree, and that each main leader appeared to function independently from the standpoint of fruiting habit. This condition was found to have held constant over a period of several years and was not necessarily confined to Yellow Newtowns, but occurred in other varieties as well.

Fruit thinning experiments conducted at Wenatchee, Washington, during the 1933–1934 seasons have again shown that heavy fruit thinning, performed within 40 days from full bloom, brought back a high percentage of blossoms and fruit on main leaders the year in which they would normally have been entirely "off." The ratio of 70 leaves per fruit, or about 1900–2000 square centimeters of leaf surface, again constituted our "heavy" thinning. "On year" leaders thinned to 50 leaves per apple, in this year's work, produced only about one-half as many blossom buds as the 70-leaf-per-apple leaders.

When the same thinning program was performed later in the season, 73 days from full bloom, very few fruit buds were formed regardless of the leaf to fruit ratios used. The percentages of blossom buds produced in 1934 from the various 1933 thinning treatments are shown in Table I.

TABLE I—EFFECT OF FRUIT THINNING ON BLOSSOM BUD FORMATION IN BIENNIAL BEARING YELLOW NEWTOWNS

Leaf-Fruit Ratio 1933	Time of Thinning 1933 Days from Full Bloom	Spurs Blossoming in 1934 (Per cent)
70 Leaves per apple	37	47
50 Leaves per apple	37	23
70 Leaves per apple	73	5
50 Leaves per apple	73	3
Commercially thinned, approximately 25 leaves per apple	52	0
"On year"	Unthinned	0.7
"Off year"	No fruit	96

Leaders thinned to 70 leaves per apple, 37 days from full bloom, formed fruit buds on 47 per cent of their spurs. With 50 leaves per apple, thinned on the same date, 23 per cent of the spurs formed fruit buds. When the thinning was delayed until 73 days from full bloom

the percentage of spurs bearing blossom buds on the 70- and 50-leaf-per-apple leaders were 5 and 3 per cent respectively. "On year" unthinned leaders differentiated less than 1 per cent blossom buds, and "on year" trees *commercially* thinned to approximately 25 leaves per apple, 52 days from full bloom, failed to form a single blossom bud. "Off year" leaders in 1933 followed their regular biennial bearing habit and differentiated 96 per cent blossom buds for 1934. These results are in absolute agreement with those previously reported (2) and it is concluded that biennial bearing in the apple can be definitely broken if a high leaf to fruit ratio is established sufficiently early in the season.

In the Pacific Northwest, with Yellow Newtowns, high in vigor, fruit thinning to 70 leaves per apple brought about the necessary leaf area to form sufficient blossom buds and a good crop of fruit the following year. However, the arbitrary number of 70 leaves per apple cannot always be considered the criterion of leaf area necessary to form fruit buds. Weakly growing trees or trees with small leaves may not respond to the thinning treatments unless a leaf area equivalent to that of 70 vigorous leaves per apple is established. In some cases this may mean 100 or even 150 leaves per apple. In our experiments we have found that considerable variation in leaf area or leaf function may exist on the same tree. A main leader on the north side, and occupying a low position on the tree, formed fruit buds on only 10 per cent of its spurs when thinned to 70 leaves per apple. Other leaders with more southerly exposures and located higher in the tree formed fruit buds on an average of 57 per cent of their spurs with the same thinning treatment. It was quite evident at the time of thinning that the high leader carried a greater area per 70 leaves than the low leader.

Time of thinning was found to be equally important to severity of thinning in upsetting biennial bearing. The importance of this time factor is shown in Table I where thinning to 70 leaves per apple as late as 73 days from full bloom failed to influence more than 5 per cent of the spurs to form fruit buds. Magness, Fletcher, and Aldrich (3) found that under Middle Atlantic conditions, little response was obtained from heavy thinning when it was performed later than 30 days from full bloom with varieties that tended to be biennial bearers. With vigorous Yellow Newtowns in the Pacific Northwest the limit of time in which buds could be effectively influenced by thinning was about 40 days from full bloom. With trees in a less vigorous growing condition than those used in this experiment the number of days from full bloom would probably have been less. The average commercial thinning dates in the Wenatchee, Washington, district for Yellow Newtowns have been from 50 to 60 days from full bloom, and this lateness of thinning in relation to the time of fruit bud differentiation may account to some extent for the general biennial condition of this variety. Such varieties as Jonathan and Rome Beauty, on the other hand, have been shown by Magness, Fletcher, and Aldrich (3) to be influenced to form fruit buds by heavy thinning within this 50 to 60 day period, and this may be responsible in part, for the general annual production of these varieties.

Our evidence, although covering only three growing seasons, indicates that once the biennial condition of the trees is broken, annual production may be maintained if careful attention is given in succeeding years to the time and degree of thinning. Following the heavy and early thinning, as shown in Table I, 47 per cent of the spurs on these thinned leaders blossomed, and practically all set fruit. Although 53 per cent of the remaining spurs were vegetative the crop was very heavy and required some thinning to insure fruit of commercial size. This thinning treatment consisted of breaking up all of the fruit clusters and adjusting the leaf-fruit ratio to 30–35 leaves per apple. Inspection of these leaders this past November showed that approximately 37 per cent of the buds have differentiated floral parts for next spring. It is therefore concluded, that annual bearing can be continued provided care is exercised in maintaining the proper leaf to fruit balance from year to year. The importance of this "follow up" thinning was demonstrated in 1932 with leaders whose biennial bearing habit was broken by early heavy thinning that year, but allowed to go unthinned the two years following. These leaders, which differentiated 60 per cent or more blossom buds following the early heavy thinning in the "on year" and which were permitted to go unthinned, reverted to their former biennial conditions *but with the crop year reversed*. In other words, the crop years on these vigorous biennial leaders were completely changed by heavy early thinning alone, when they were not thinned the following season.

On the other hand, if the leaf to fruit ratio was not great enough to influence a rather high percentage of the spurs to form fruit buds, and this sometimes occurred with 50 leaves per apple, the leaders tended to return to their biennial condition. In this case the crop years remained unchanged.

It is apparent that an excessively heavy fruit thinning the first year, and subsequent "follow up" adjustments are essential if biennial bearing is to be broken and annual production maintained.

Individuality of Main Leaders

In certain physiological investigations of apple trees it is often desirable to make detailed studies of certain portions of a tree rather than the entire tree. Influences such as stock and scion, soil types, tree vigor, etc., always tend to introduce variables which are difficult to eliminate if different trees are used. The practice of ringing branches has been employed to a large extent in a partial isolation of particular branches from the influence of adjacent portions of the tree. This method has been especially effective in the study of carbohydrate metabolism and other products of leaf manufacture. Regardless of the many excellent discoveries which are based on ringing, however, the practice is open to some well founded criticisms. Studies on small unringed branches are even less reliable for it has been shown by Haller (1) that elaborated foods can be transported to distances of from 4½ to 10 feet from the point of origin.

Evidence secured in the present study indicates that individual main leaders may function independently from the remaining portions of the tree insofar as the transport of elaborated materials is concerned.

As stated before, one or two main leaders on Yellow Newtown trees may be definitely in an "off," or "on year" condition regardless of the fruiting habit of the remaining leaders. Also, a careful study of the spur performance of these leaders has shown this individuality to hold true over a period of several years. Further confirmation of these observations was obtained in experiments conducted during the past two seasons. Trees were selected which were entirely in the "off year" and a single leader defoliated to one large leaf per spur. In 1933 the date of defoliation was June 13, or 44 days from full bloom. In 1934 the single leader was defoliated to one leaf per spur 30 days from full bloom.

TABLE II—EFFECT OF DEFOLIATING INDIVIDUAL MAIN LEADERS OF "OFF YEAR" TREES TO ONE LEAF PER SPUR ON FRUIT BUD FORMATION

Treatments	Time of Defoliation (Days from Full Bloom)	Fruit Buds Formed (Per cent)
Defoliated to 1 leaf per spur 1933	44	1.0
Defoliated to 1 leaf per spur 1934	30	0.0
Remaining leaders of "Off Year" tree 1933	Untreated	97.0
Remaining leaders of "Off Year" tree 1934	Untreated	98.0

The resulting data show that only 1 per cent of the spurs on the 1933 defoliated leader formed fruit buds, while 97 per cent of the spurs on the untreated leaders differentiated fruit buds. Examination of the spurs defoliated in 1934 was made this past November and no buds were found with floral parts on the defoliated leaders, while the untreated leaders on the same tree formed 98 per cent fruit buds. It is probable that the 1 per cent of fruit buds, found on the leader defoliated in 1933, had differentiated prior to defoliation, for it has already been stated that 44 days from full bloom was beyond the time buds could be completely influenced by leaf adjustment.

It is concluded from these experiments that fruit bud formation is wholly dependent upon the leaf activity of the main leaders on which they occur. The results also suggest that the factors which determine fruit bud initiation are produced in the same season that differentiation takes place, rather than from reserve materials in the tree.

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Bulk Fruit Thinning and Wide Spacing of Newtown Apples

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THE following report presents data respecting a fruit thinning experiment with Newtown apple trees at Hood River during 1933. Differences in yield, size of fruit, and spur performance in response to thinning are distinct.

Three, medium large, uniform Newtown trees 25 years of age were each given a different type of thinning. All were vigorous, moderately dense and were given a light annual pruning during early spring. The trees bloomed heavily and weather conditions favored "set." On June 10, the date of thinning, the number of apples per fruiting spur on trees 1, 2, and 3 was 3.6, 3.4, and 3.1 apples, respectively. This date was before the "June drop" and apples were about the size of a hazelnut. The trees were distinctly alternate bearing having produced no crop in 1932.

Tree 1 was thinned in a manner herein referred to as "bulk thinning." In this case the tree was uniformly divided into eight equal areas by perpendicular planes extending from the center to the circumference. All apples within four of these alternate sections of the tree as described (representing one-half of the total bearing area) were removed in the following numbers: 2350, 2130, 1820, and 850 or a total of 7150 thinnings. A smaller number of apples were growing on the southwest side of the tree where vigor and extent of bloom were less than was true of other areas. On the remaining four alternate sections, spurs were thinned completely, or to one apple. Spacing was 5 to 6 inches between fruits. The number of thinnings was 1240, 1796, 666, and 291 from respective sections or a total of 3993. Thus the total number of thinnings from the entire tree was 11,143.

On tree 2 fruiting spurs were uniformly spaced ten to twelve inches apart and thinned to one apple each. All apples on remaining spurs were removed. The total number of thinnings was 11,540 closely approximating that of tree 1.

Tree 3 was thinned lightly with spacing of apples similar to that done on bearing portions of tree 1. The total number of thinnings was 7,561.

Fruit-leaf ratios established by thinning were as follows: Tree 1, (within bearing sections) 1–12.4, and for the entire tree an estimated ratio of 1–24; tree 2, 1–25; and for tree 3, 1–11.4. Although thinning of trees 1 and 2 differed widely in character, fruit-leaf ratios applicable to the entire tree were approximately the same.

The growing season was normal in most respects in 1933 except during early August when relatively high daily temperatures prevailed. A small per cent of fruit was sunburned and growth was definitely retarded.

Fruit was picked October 12. The number of apples harvested is in general agreement with the character of thinning done (Table I). Tree 3 matured 5,462 apples, or nearly double that of trees 1 and 2

which produced 3,402 and 3,022 apples, respectively. Yields for trees 1, 2, and 3 in the order given were 23.1, 22.5, and 31.1 loose boxes.

Size of fruit at harvest was determined by the number of apples per box (level—unpacked) and by the packout (Table I). The average number of apples per unpacked box for trees 1, 2, and 3 was 147, 134, and 175, respectively. Although the character of thinning within bearing sections of tree 1 was similar to that done on tree 3, apples from the former were much larger than those from the latter. The probable explanation for this fact is that leaves within non-bearing sections of tree 1 exerted a remote but potent influence upon size of fruit within the remaining areas. Apparently this influence was less potent than was true with tree 2 which produced larger fruit than tree 1. With respect to this fact, it is emphasized that fruit-leaf ratios for the two trees were practically the same but that proximity of leaf and fruit in each case differed materially. These factors are of prime commercial importance because requirements are for a medium size apple and highest average prices are paid for those packing 138–163 per box.

TABLE I—Yields per Tree, Size of Fruit, and Packout*

Field, Size, and Value	Character of Thinning		
	Bulk Thinning (Tree 1)	Wide Spacing (Tree 2)	Narrow Spacing (Tree 3)
Apples harvested			
1933	3402	3022	5462
1934	483	1163	20
Total	3885	4185	5482
Boxes (loose) harvested			
1933	23.1	22.5	31.1
1934	5.25	14.0	.25
Total	28.35	36.50	31.35
Number of packed boxes each containing			
125 or more	—	1.11	—
138 to 163	5.6	7.86	4.3
175 to 213	10.9	6.89	13.9
263 to 306	1.3	1.36	7.2
Total	17.80	17.22	25.4
Estimated value†	$20.57	$19.94	$27.11

*All data apply to 1933 except where otherwise noted.

†Based on following prices: 125 or larger packed box, $1.00; 138–163, $1.25; 175–213, $1.15; and 263–306, $0.80.

Fruit from tree 3 had greatest value in 1933. This was estimated at $27.11 versus $20.57 and $19.94 for trees 1 and 2. This difference was due to greater yields rather than value of fruit per packed box which was for trees 1–3 in the order indicated, $1.15, $1.16, and $1.07. Had growing conditions during August been more favorable size of fruit would undoubtedly have been larger with both yield and value of fruit greater.

Bloom and production of fruit in 1933 was studied on an individual spur basis (Table II). Data for this purpose were taken from large

representative limbs. It is notable that only 21.7 per cent of spurs on tree 2 bore fruit versus 45.4 and 47.9 per cent for bearing portions of tree 1 and 3, respectively. The per cent of blossom spurs which were non bearing in 1933 due to thinning or to drop was not determined. Such drop, however, was light particularly with trees 1 and 2 and somewhat heavier with tree 3.

A study of the same individual spurs in 1934 (Table II) indicate the following per cent of bloom within the areas as follows: tree 1, sections completely thinned in 1933, 22.6, and sections which bore, 2.2; tree 2, 24.5; and tree 3, 1.6. These percentages in relation to total bloom in 1933 in trees or portions of trees as above indicated bear the following proportions: 1–3.2; 1–31.7; 1–2.4; and 1–40.9.

TABLE II—PERCENTAGE OF SPURS BLOOMING IN 1934 IN RELATION TO BLOOM AND FRUITING IN 1933

Treatment	Year	Character of Spurs	Bearing	Blooming, Non-bearing	Non-blooming	Total (Per cent)
		Bulk Thinning 1933 (Tree 1)				
a. All apples removed	1933	Per cent	—	*72.1*	*27.9*	*100*
	1934	Blooming	—	16.3	6.3	22.6
		Non-blooming	—	55.8	21.6	77.4
b. Narrow spacing	1933	Per cent	*45.4*	*24.4*	*30.2*	*100.0*
	1934	Blooming	.6	0.0	1.6	2.2
		Non-blooming	44.8	24.4	28.6	97.8
		Wide Spacing 1933 (Tree 2)				
	1933	Per cent	*21.7*	*37.0*	*41.3*	*100.0*
	1934	Blooming	1.35	7.7	15.5	24.55
		Non-blooming	20.35	29.3	25.8	75.45
		Narrow Spacing 1933 (Tree 3)				
	1933	Per cent	*47.9*	*17.5*	*34.6*	*100.00*
	1934	Blooming	0.0	.00	1.6	1.6
		Non-blooming	47.9	17.5	33.0	98.4

Performance of spurs in 1933 shown in italics and that of the same individual spurs in 1934 not italicized.

A higher proportion of non blooming spurs in sections of tree 1 completely thinned in 1933 produced bloom in 1934 than was true of the balance of the tree. These relations are represented in proportions of 1–4.4 and 1–1.9. Similar relationship with trees 2 and 3 are in proportions: 1–2.6 and 1–21.6.

The proportion of blooming but non-bearing spurs of 1933 which showed repeat bloom in 1934 was: Tree 1 (completely thinned sections) 1–4.4, and with bearing sections, no bloom; Tree 2, 1–4.8 and Tree 3, no bloom. Bearing spurs showed a negligible repeat bloom in 1934.

Fruit-bud Differentiation in the Sugar Prune

By C. H. RAGLAND, *University of California, Davis, Calif.*

THE time of fruit-bud differentiation has been determined for many stone fruits and found to vary from June to September, depending upon the variety and location. Hartwell (1) reports fruit-bud differentiation in the French prune to have begun by June 29 in 1920, while Tufts and Morrow (2) give mid-August as the time of differentiation in 1923. This seems to indicate more variation than one would expect from varying climatic conditions since collections were made at Davis, California, in both instances. A study of the plates in these papers does not show the variation to be as great as reported, but suggests a difference of 3 to 4 weeks between similar stages of development. This would be less difficult to attribute to seasonal variations or other environmental conditions.

In the work now reported samples were collected from non-fruiting Sugar prune trees, growing on the University Farm at Davis, at 2-week intervals, beginning May 9, 1934. Buds were killed and fixed in formalin alcohol solution, treated in the usual manner for paraffin embedding, and sectioned with a rotary microtome.

By June 4 the growing point appeared slightly broadened and one week later differentiation had definitely begun. On June 9 the growing point had slight protuberances, representing the primordia of individual flower buds. By June 21 these primordia had elongated considerably, and 1 week later, the calyx primordia were well advanced with the petal primordia appearing by July 8. Fig. 1 illustrates typical development from May 21 to June 29, 1934.

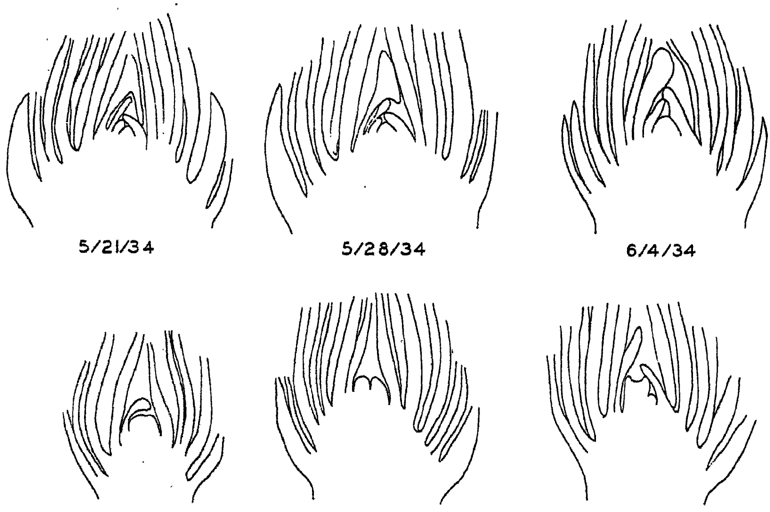

FIG. 1. Fruit-bud development in the Sugar prune from May 21 to June 29, 1934. Fruit-bud initiation is evident on June 9.

Fruit-bud differentiation seems to occur rather uniformly in all buds from non-bearing Sugar prune trees. If it is possible to stimulate fruit-bud formation and thus encourage annual bearing in this variety by thinning the fruit or applying other cultural treatments, it would probably be necessary to apply the treatment before the time fruit-bud initiation takes place in non-bearing trees. The 1934 season was somewhat earlier than normal, and it is probable that fruit-bud differentiation was correspondingly advanced. Even so, it is very probable that fruit-bud differentiation begins before July 1 in other years.

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The Influence of Sugar, Nitrogen Fertilizers, and of Ringing Gravenstein Apple Trees Upon Color and Maturity of the Fruit

By F. W. ALLEN, *University of California, Davis, Calif.*

NUMEROUS investigations to determine the influence of nitrogenous fertilizers upon fruit have shown that they usually result, indirectly at least, in somewhat later ripening and in less color. Other fertilizers or materials added to the soil with the idea of hastening ripening or increasing color generally have yielded negative results. Fletcher (1), however, reducing the nitrate content of the soil by applying sugar, reports earlier maturity and, in some instances, an increase in color of several varieties of apples.

Owing to the importance of the Gravenstein as an early shipping variety and its usual lack of color when harvested, any means of increasing either color or earliness would be of great commercial value. In connection with the studies upon rate of ripening and bitter-pit development in Gravenstein apples previously reported upon (2), trials similar to those of Fletcher were made on this variety during the past two seasons.

1933 TRIALS

Two trees in each of three different orchards in the Sebastopol apple section were each treated on May 25 with 50 pounds of corn sugar dissolved in 125 gallons of water and injected into the soil area under the branches to a depth of 3 to 4 feet. The soil in each of the orchards was similar, being a sandy loam with a considerable mixture of gravel. All the trees were 25 to 30 years of age; those in one orchard were only moderately vigorous while those in the other two were vigorous to very vigorous. Two rather vigorous 11-year-old trees on a deep clay loam soil in the University Farm orchard were likewise treated, while two additional trees received 50 pounds each of calcium nitrate dissolved and applied in the same manner as the sugar. Certain branches of still other trees were girdled in an attempt to change their normal nitrogen-carbohydrate ratio. Before applying the sugar and nitrate, and at 10-day intervals until the crop was harvested, soil samples were taken in foot-increments to a depth of 4

TABLE I—NITRATES IN SOIL FROM ORCHARD OF RATHER LOW VIGOR AT SEBASTOPOL, CALIF., 1933

(FIGURES IN PARTS PER MILLION OF DRY SOIL)

Date	Soil Samples: 0–2 Feet		Soil Samples: 3–4 Feet	
	Sugar-treated Trees	Check Trees	Sugar-treated Trees	Check Trees
June 3	0.7	8.7	0.3	2.5
June 13	1.9	4.6	0.0	0.0
June 23	0.5	5.5	0.2	2.5
July 3	0.3	1.8	0.0	6.3
July 13	0.7	1.4	0.3	1.0

feet from the Sebastopol orchard of lowest vigor, and from the University Farm orchard, and analyzed for nitrates.

Results:—Nitrates in the Sebastopol orchard, originally lower than in the University Farm orchard, were rather markedly reduced by the sugar treatment (Table I).

The addition of sugar to the University Farm orchard seemed to have some influence on the nitrate content of the soil, although the results were not consistent. The heavy calcium nitrate application did result in material nitrate increase (Table II), but the trees failed to show any response to its application.

TABLE II—NITRATES IN SOIL FROM ORCHARD OF GOOD VIGOR OF UNIVERSITY FARM, 1933

(FIGURES IN PARTS PER MILLION OF DRY SOIL)

Date	Soil Samples: 0–2 Feet			Soil Samples: 3–4 Feet		
	Sugar-treated Trees	Check Trees	Nitrate Treated Trees	Sugar-treated Trees	Check Trees	Nitrate Treated Trees
June 4	8.8	3.7	127	3.2	3.9	250
June 14	10.5	14.3	200	1.5	8.4	126
June 24	1.7	12.0	225	0.0*	2.5	80
July 4	9.8	4.3	238	7.2	0.0	205†
July 14	1.5	1.2	185	0.3	1.9	148

*4th foot only.
†3rd foot only.

Fruit from the four experimental orchards was harvested between July 12 and 26 when of maturity usually considered satisfactory for shipment. Careful color comparisons were made both before and after harvesting. Pressure tests for firmness and refractometer readings of soluble solids were taken on 20 representative specimens from each tree when picked. Fruit from the sugar-treated trees in the University Farm orchard was slightly firmer and averaged 0.5 per cent higher in soluble solids than the fruit from the nitrate trees. Aside from this difference, which was considered of little if any significance, no other differences were noted in any of the samples. The sugar had materially reduced the nitrates in the soil of the Sebastopol orchard and caused some reduction in the University Farm orchard. In neither instance however was the color or firmness of the fruit affected. A limited number of apples from girdled limbs on untreated trees averaged slightly higher in soluble solids than those from non-girdled limbs, but again no other differences were discernible.

1934 TRIALS

During the past season the trees in the University Farm orchard were again treated with sugar and nitrate. Cane sugar was substituted for corn sugar and ammonium nitrate for calcium nitrate. Applications of 50 pounds of nitrate and of sugar were made on March 28 and again on May 2. A third application of sugar was made May 24. At each application the material was scattered over the soil and the trees heavily irrigated by flooding. Main scaffold limbs of both treated and untreated trees were girdled with a ½-inch girdle on May 2.

Results:—On June 13, after some dropping had occurred, half the crop was considered ready for harvesting. At this time again there was no appreciable or consistent difference in color or firmness of fruit from any of the trees. Fruit from the sugar-treated trees did, however, show a 10 per cent increase in soluble solids over that found in the apples from either the check or nitrate-treated trees. Ten days later when the second and final picking was made the percentage of soluble solids in the sugar and nitrate trees was identical. Chemical analyses likewise failed to show any greater amount of sugar in the former than in the latter.

The most definite results of the test were secured from ringing. With the exception of one tree, fruit from girdled limbs was consistently higher in soluble solids and in reducing and total sugars than that from non-girdled limbs (Table III).

TABLE III—SOLUBLE SOLIDS AND SUGAR IN GRAVENSTEIN APPLES FROM GIRDLED AND NON-GIRDLED BRANCHES (UNIVERSITY FARM ORCHARD, 1934)

Tree No.	Percentage of Soluble Solids				Percentage of Sugars, June 23					
	June 13		June 23		Reducing		Sucrose		Total	
	Girdled	Non-girdled	Girdled	Non-girdled	Girdled	Non-girdled	Girdled	Non-girdled	Girdled	Non-girdled
1........	11.2	7.8	14.6	11.0	6.7	6.2	1.3	1.2	8.0	7.4
2........	10.0	9.2	12.2	10.8	6.4	6.0	1.4	1.4	7.8	7.4
3........	—	—	—	—	6.6	6.0	1.6	1.5	8.2	7.5
4........	10.4	9.9	12.6	12.0	6.3	6.9	1.6	1.7	7.9	8.6
5........	10.3	9.4	12.0	11.0	6.3	6.1	1.5	1.3	7.8	7.4
6........	10.2	9.0	11.2	10.8	6.3	5.4	1.5	1.8	7.8	7.2
Average	10.4	9.0	12.3	11.1	6.4	6.1	1.4	1.4	7.9	7.6

In some instances the girdled limbs produced fruit of a more yellowish-green color or with a more pronounced streaking of red. The latter was more noticeable some 10 days after harvesting than when picked. Although all samples of fruit harvested June 22 gave pressure test readings 2 to 3 pounds below those of fruit picked 10 days previously, apples from girdled limbs were no softer when picked than those from non-girdled limbs. In fact, on the above date the former were slightly firmer—greater firmness frequently being associated with sugar content and color development.

DISCUSSION

Although the above trials were limited in scope, the results to date indicate that not only did heavy applications of nitrogen fail to retard maturity, but that it is doubtful if lowering the nitrates in the soil through the application of sugar has any economic value in either hastening maturity or increasing color development of Gravenstein apples grown in California. Were the fruit allowed to attain its full color development before harvesting, as usually is done with red varie-

ties, more marked differences might be anticipated. As previously mentioned, however, the Gravenstein, normally harvested early in July, when showing little change in ground color and with little or no red color development, has only a very limited time to respond to any color treatment. Temporarily, changing the nitrogen-carbohydrate relationship in the limbs by girdling did appear to give some slight color increase.

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Some Experiences With the Thornton Test for Potash in Apple Trees

By J. K. SHAW, *Massachusetts State College, Amherst, Mass.*

NUMEROUS tests for the available phosphorus and potassium in the soil have been proposed and their use with field crops seems helpful. In the case of tree fruits, it has been shown that plenty of phosphorus and potassium in the soil may not insure a suitable supply in the tree. The reason given is the fixing power of the soil for these elements. Tree roots are usually deeper than those of annual crop plants and this suggests that these elements may be fixed in the soil before they can penetrate to the zone of the feeding roots. Therefore a reasonably dependable test for the amount of these elements in the tissue of the tree should be helpful in suggesting fertilizer needs and soil treatment of orchards.

Recently Thornton has published methods for determining the relative abundance of phosphorus and potassium in the tissues of field crop plants and shows that these tests give results closely paralleling fertilizer treatments and offer means of distinguishing plants deficient in these two elements (3, 4).

At the Massachusetts Station we have several comparable plots which have been fertilized with potash carrying materials for periods of varying length. These can be compared with other plots that have received no potash fertilizer. The potash fertilized trees present a better appearance and in most cases have yielded more than other trees fertilized with nitrogen only. Thus we have a good opportunity for studying the value of the Thornton test.

SAMPLING TECHNIQUE

The most suitable part of the apple tree to use was found to be the leaf petioles. These were cut in fine pieces with a sharp knife. It was found that care must be taken to cut all samples uniformly. Three samples cut into pieces about 1 mm in size were all rated as L while three of the same material cut as finely as possible were rated H, VH, and Ex H[1]. Too wide variations in weight of samples used should be avoided. Samples of 200, 400, and 600 mg gave precipitates rated as H, VH, and Ex H. Small variations in amount are within the error of estimation of the amount of precipitate. One should cut all petioles as uniformly as possible and either weigh or measure the sample, at least until one has had considerable experience.

Samples of petioles from various parts of one young tree were tested in duplicate. These were as follows:—near tip of shoot, near base of shoot, large spur leaves, small spur leaves, four different short interior shoots, the lower half of the midrib, and the leaf blade. One duplicate gave a precipitate rated as H while the other nineteen tests were rated as VH. It was concluded that the location in the tree from which the sample was selected makes little difference. From four

[1]The amount of potash is recorded as follows: O = none, T = trace, L = light, M = medium, H = heavy, VH = very heavy, and Ex H = extremely heavy.

to six petioles usually give sufficient material for a single test. The cut leaf blade is satisfactory except that the material in the solution obscures the reading somewhat. Sections from the tip of the growing stem gave low readings.

Samples from a particular tree taken at different times for a space of two months showed some differences. A tree rated as L at one time, might be rated M or possibly H but rarely VH. Further study is necessary to determine if the time of sampling is of any importance.

Results Obtained

Many tests were made on McIntosh and Wealthy trees planted in 1928 in a field which has had fixed applications of nitrogen, phosphorus, and potash for 45 years. Discussion of the growth of trees on these plots has been published (1, 2). The results of some of these tests together with some other pertinent information is given in Table I.

TABLE I—Available Potash and Tree Performance

Fertilizer Treatment	Available Potash		Index of Leaf Burn		Tree Caliper (Mm)	
	Not Limed	Limed	Not Limed	Limed	Not Limed	Limed
O	0.1	0.6	1	76	41	34
N	0.7	1.5	4	132	39	31
P	3.7	0.7	4	27	42	37
O	3.2	1.2	48	4	40	37
K	3.7	4.2	171	10	37	41
NP	3.5	0.3	27	53	45	38
NK	4.7	3.2	281	13	36	45
PK	1.5	2.7	580	34	31	39
NPK	4.7	4.2	240	22	39	42
NPK	4.0	4.0	260	6	36	37
NPK	4.2	3.0	195	9	37	44

Each figure for available potash is the average of tests on four trees.

The available potash tests have been computed by assigning the value 0 where no precipitate came down, up to 5 when the precipitate was very heavy. Therefore, if all trees tested rated very high, the value would be 5. Notes were taken of the percentage of leaf area destroyed by leaf burn. These figures are arbitrary values where 0 represents no burn while 800 would indicate that all the leaf area on all trees on the plot was destroyed. The trunk diameter is also given. The average size of the trees in the several plots was the same when planted. One half of each plot has been limed, the pH value of the soil being about 6.2. The other half has not been limed and the pH value is about 4.8.

The potash content of the trees in the limed potash plots as indicated by the tests is high except on the phosphorus-potash plot. This suggests that in the absence of a nitrogen carrying fertilizer, potash absorption is decreased. On one of the check plots the potash is high. There are no consistent differences between the limed and unlimed parts of the plots except in the two plots fertilized with phosphorus but without potash. Here the trees on the unlimed parts show higher potash. This has been checked and always with similar results. The

three complete fertilizers are made up with different carriers. There seems to be no significant difference in potash content.

The figures for leaf burn are interesting. On the unlimed plots burn is more severe on the potash fertilized plots; on the limed plots no such difference appears. Growth as measured by trunk diameter, is negatively correlated with leaf burn.

In order to check this test, determinations of potash by the official Lindo-Gladding method were made on the leaves of the trees from six of the plots[1]. The results are shown in Table II together with the results from the Thornton test for the same plots taken from Table I. The check plot is high in comparison with the Thornton test but the other five determinations are in agreement as to whether the potash content is high or low.

TABLE II—COMPARISON OF OFFICIAL METHOD WITH THORNTON TEST

Fertilizer Treatment	Potash by Official Method Per cent of Dry Matter		Potash by Thornton Test From Table I	
	Not Limed	Limed	Not Limed	Limed
O	.299	—	0.1	—
P	.310	.108	3.7	0.7
NP	.305	.180	3.5	0.3
NPK	—	.397	—	4.2

Table III gives the variations among trees on several plots in two orchards. The first is the orchard discussed above and the second an 18-year-old Wealthy orchard in sod which has had the indicated dif-

TABLE III—VARIATION IN POTASH CONTENT

Fertilizer Treatment	Not Limed				Limed			
	McIntosh		Wealthy		McIntosh		Wealthy	
Cultivated Orchard								
Nitrogen	L	O	T	O	M	L	T	O
Phosphorus	M	H	VH	M	T	O	L	O
Nothing	M	M	H	M	T	M	T	O
Nitrogen-Potash	VH	H	VH	VH	M	H	M	M
Phosphorus-Potash	T	T	L	L	L	L	H	M
Complete	VH	M	VH	VH	H	H	VH	H
Complete	H	H	H	VH	H	H	H	H
Sod Orchard	Wealthy							
Phosphorus-Potash	H	VH	H	L	M			
Nitrogen	O	O	T	M	T			
Nitrogen	O	M	T	T	T			
Nitrogen-Potash	M	H	M	M	L			
Nitrogen-Potash	VH	H	M	VH	H			
Complete	VH	T	VH	H	H			
Complete	L	VH	H	L	M			
Complete	VH	H	H	VH	—			

[1]For these determinations the author is indebted to H. R. DeRose of the Control Laboratory.

ferential fertilizer treatments since 1927. Each entry represents the test of a single tree. While the tests correlate with fertilizer treatment fairly well, there are considerable differences between the trees on a single plot especially in the sod orchard.

This bearing Wealthy orchard has seemed to respond to potash over nitrogen alone with increased yields. In Table IV are shown the number of trees giving from none to very heavy precipitate and the average yield of these trees for 1932 and 1933. A 2-year yield is taken because some trees bear in the even and some in the odd year. The figures suggest some relationship between the potash reaction and yield.

TABLE IV—Available Potash and 1932–33 Yields (Lbs.)—Wealthy

Available Potash	PK Only		N Only		NK and NPK		Total	
	No. Trees	Ave. Yield	No. Trees	Ave. Yield	No. Trees	Ave. Yield	No. Trees	Ave. Yield
O.........	0	—	2	183	0	—	2	183
T.........	0	—	4	284	1	251	5	277
L.........	1	169	0	—	3	307	4	272
M........	1	80	2	380	5	355	8	327
H........	2	230	0	—	11	392	13	367
VH.......	0	—	0	—	7	382	7	382

Many tests were made of leaves from trees growing in an orchard under strip cultivation with fairly liberal fertilization with nitrogen only and which seems to have suffered from potash deficiency. Table V shows the results of tests of trees which have never received a potash fertilizer, others fertilized in 1934 only, and still others fertilized in 1931, 1933, and 1934. Each entry represents the test on one tree. Evidently little of the potash applied in 1934 had been absorbed by August while the trees receiving potash for 3 years have generally absorbed what may be fairly adequate amounts. Wagener seems to lack absorbing capacity. It also shows very poor performance in this orchard.

TABLE V—Block B Available Potash—Leaf Petioles

Variety	Potash Fertilization		
	No Potash	Potash 1934	Potash 1931, 1933, 1934
Baldwin....................	O	T	VH
Rhode Island Greening.......	M	O	T
Wagener, fruiting trees.......	O	O-O-O-O	M-VH-O
Wagener, non-fruiting trees...	O-O	O-O-T-M	O-H-T
McIntosh..................	O	T	H M
Northern Spy...............	O	———	H
Wealthy...................	T	H-L	H
Fall Pippin.................	———	O	VH

Inasmuch as our own orchards seem to begin to show signs of potash deficiency, the question arises as to how this situation may be. Between 50 and 60 samples of leaves from 10 different orchards over

the state have been tested. Only one of these orchards seems, by this test, deficient in potash.

This test for potash in apple leaf tissue is rapid and simple only requiring a rather rigid similarity of technique with the different samples and seems to indicate differences between high and low potash content of the trees. With more experience it may be possible to use it as a tool in improved orchard fertilization.

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The Translocation of Nitrogen in Woody Plants

By W. E. Loomis, *Iowa State College, Ames, Ia.*

THE importance of the physiological and economic aspects of nitrogen fertilization of fruit trees are universally recognized and have been the subject of extensive investigation. Unfortunately, one of the important points in nitrogen physiology, the method of its accumulation and movement through the plant, has been a matter of dispute. It is hoped that the data and hypothesis presented will assist in placing the study of nitrogen metabolism and the problems of nitrogen fertilization of woody perennials upon a more satisfactory basis.

Experimental

Five-and-15-year-old apple trees, 3-year-old poplar whips, and 8- to 15-year-old box elder seedlings have been used as experimental material. Phloem rings protected by paraffin were used to affect translocation. Chemical samples were analyzed by methods previously given (2).

More than 100 samples of bark and wood of the above species, collected at all seasons of the year, have been analyzed for total nitrogen and for the nitrate and nitrite, ammonia, amid, amino, basic, "other" soluble organic, and protein nitrogen fractions. None of these analyses have shown significant quantities of inorganic nitrogen in any of the above ground tissues of these plants. These results correspond to those of Thomas (6) and indicate (a) that inorganic nitrogen is synthesized in the roots of woody plants and (b) that nitrogen translocation, so far as the top is concerned, is normally confined to the movement of organic nitrogen.

The nitrogen of the trunk of poplar:—Analyses at three dates, of check and variously ringed three-year-old poplar trees are given in Table I. These data show (a) that half of the nitrogen of the bark of the check trees was digested and moved from the trunks in the first

TABLE I—The Effect of Phloem Rings upon Nitrogen Distribution in the Trunk Bark of 3-year-old Poplars

Treatment	Mgs in 100 Gm Fresh Sample				
	April 28 (Dormant)	May 23 (Leafing)		June 17 (Well Grown)	
		Analysis	Change from 4/28	Analysis	Change from 4/28
Soluble Org. N of					
Check	74.7	60.3	−14.4	58.7	−26.0
Below rings	58.7	161.3	+102.6	169.3	+110.6
Between rings	74.7	155.4	+80.7	77.3	+2.6
Above rings	65.3	76.0	+10.7	46.1	−19.2
Protein N of					
Check	442.3	237.8	−204.5	193.1	−249.2
Below rings	395.0	411.5	+16.5	304.2	−90.8
Between rings	442.3	415.0	−27.3	247.3	−195.0
Above rings	467.4	257.5	−209.9	217.8	−249.6

4 weeks of the growing season, (b) that this loss of nitrogen was delayed 4 to 6 weeks by phloem rings above the area studied, and (c) that soluble organic nitrogen accumulated below the rings to two or three times its normal concentration.

The extent of digestion indicates that reserve proteins are important in spring growth and suggests an explaination for the effectiveness of continued applications of slowly available nitrogenous fertilizers reported by Schrader and Auchter (5). The accumulation of soluble organic nitrogen below the rings, but not above, is evidence that this material is moved upward in the phloem. Analyses of the leaves on the ringed branches of poplar and apple showed them to contain only about two-thirds as much nitrogen on either a green weight or an area basis as the leaves on unringed trees or branches. Twig growth on small ringed branches suffered severely the first season, and the entire branch frequently died in July. Twig growth on large branches with a larger supply of nitrogen stored as protein was nearly normal the first season after ringing, but fell almost to nothing the second season (Table II) with an accompanying low nitrogen content. All of these observations support the hypothesis of extensive storage of organic nitrogen in trees and of its upward movement in the phloem after digestion.

The late season loss of soluble and protein nitrogen from the region between the rings (Table I) is considered to be an important clue to the mechanism which differentiates xylem and phloem translocation. The between-the-rings sections were visibly injured by the treatment, at or soon after the time of observed nitrogen loss, and many of them died 8 to 10 weeks after ringing. We interpret the failure of the rings to hold the nitrogen over extended periods as a pathological symptom associated with increased permeability in the affected cells. Martin (3) and others have shown that adjoining, living cells are connected by plasmodesms which are destroyed when one of the cells dies, as for example when it becomes a tracheal element. Many experiments have shown that normal plant cell membranes are very slowly permeable to sugars and other organic compounds. It seems safe to assume then that these food materials which are known to move readily between living cells, move through the plasmodesms. With the lack of plasmodesmal connections between the storage cells and the tracheae, the movement of *organic* materials into the transpiration stream will depend upon high permeability of the membranes of the xylem parenchyma and will not be important in normal plants. Inorganic ions, on the other hand, must penetrate one membrane to enter the plant, and, if they remain unchanged, should be able to pass through another membrane into the xylem where they could be moved upward in the transpiration stream.

The relation of root reserves to nitrogen movement:—Since nitrate and ammonia ions can be shown to penetrate the root membranes, their failure to pass into the transpiration stream is explained on the basis of their rapid synthesis to organic forms as observed by Thomas (6) and corroborated by our analyses. The formation of organic nitrogen in the roots should be dependent, among other factors, upon an available carbohydrate supply. The data in Table II show that

ringed limbs on apple trees, the roots of which had a low carbohydrate supply, contained more nitrogen and made more growth than similar limbs on normal roots. The first season after treating, the large ringed branches in this experiment all showed good growth, presumably on stored nitrogen. In the second season the ringed branches on normal roots showed acute nitrogen starvation with a very small terminal growth whereas two trees on which most of the branches had been ringed or removed so as to leave a deficient photosynthetic area attached to the roots, showed good twig growth and normal nitrogen percentages above the rings. These results support the hypothesis that the nitrogen of trees normally moves upward in the phloem because it is organic nitrogen, and remove the conflict between the work of Curtis (1) who found nitrogen movement checked by phloem rings in trees and that of Maskell and Mason (4) who found *inorganic* nitrogen to move past a phloem ring in cotton. The difference appears to be in the region of the formation of organic nitrogen compounds in the two plants and not in the fundamental physiology of translocation.

TABLE II—SPROUT GROWTH AND NITROGEN CONTENT OF APPLE BARK THE SECOND SEASON AFTER RINGING

Measurement	Normal Limbs	Ringed Limbs, Normal Roots	Ringed Limbs, Starved Roots
Average apical growth (cm)...	37.0	2.5	21.5
Total nitrogen (per cent green weight).................	0.311	0.209	0.294

SUMMARY

1. Large quantities of protein nitrogen were found to be stored in the bark and wood of trees, whence it was digested and used in early spring growth. The success of fall nitrogen applications and the cumulative effect of nitrogen fertilization with ammonia are probably related to this storage.

2. Nitrogenous salts appear to be synthesized to organic compounds in the normal roots of apple and other trees, and as a result of this synthesis to be readily translocated only in the phloem. It follows that ringing stops the upward movement of nitrogen in these plants as well as the downward movement of carbohydrates.

3. Nitrogen has been found to move upward past a phloem ring under two conditions: (a) when the storage tissues were showing injury as a result of a continued ringing treatment, and (b) when the carbohydrate level of the roots was reduced to a low value. On the basis of these and other observations we advance the hypothesis that inorganic nitrogen can pass through normal cell membranes into the transpiration stream, but that organic nitrogen does not readily penetrate these membranes and in consequence its movement, both upward and downward, is normally confined to the plasmodesmal connections existing between living cells and especially developed in the phloem.

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Nitrogen Intake and Growth Response in Peach Trees Following Fall and Spring Fertilizer Applications

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IN view of the extensive use of nitrogen fertilizers for peach trees and the increasing interest in fall rather than spring application, information was sought on the responses of peach trees to different nitrogen carriers applied in the fall and spring; also on the time and relative amounts of nitrogen absorbed by the trees following these applications.

The present study was begun in 1932 in a 7-year-old Elberta orchard located near Warrenton, Virginia, about 50 miles southwest of Washington, D. C. The soil, a clay loam of shale origin, had an initial pH of 6.3. The trees had received no nitrogen the previous year, no pruning, and little cultivation; consequently, they were extremely low in vigor. Obviously a nitrogen-deficient condition existed and marked responses from fertilizer treatment were to be expected. Plots, including 8 to 10 trees each, were given 3 pounds of nitrate of soda or its equivalent in nitrogen in either calcium cyanamid or sulphate of ammonia, applied either in the fall, spring, or in a split treatment, half in fall and half in spring. Fall applications were made about October 15, before defoliation was complete, and spring applications during the first week in April, just prior to full bloom. Leaves, terminal shoots, and roots ¼-inch or less in diameter were analyzed at intervals for total nitrogen, including nitrate. Results of growth measurements and analyses of leaves are summarized in Table I.

Effects of the first fall application of nitrate of soda were evident in the darker green foliage the following spring. Also, samples taken April 4 contained 20 per cent more nitrogen in the twigs and roots of the fall-treated trees than in the check (Data not included in tables). A similar increase was noted a month later in twigs and roots of spring-treated trees. However, the spring nitrate of soda plot soon surpassed the fall-treated plot in apparent vigor, in accord with the much higher nitrogen content of the leaves on May 15 and June 20, 1933 (Table I). As a result the terminal growth was 2 inches longer than that of the fall-treated plot. The split application plot equalled the latter in terminal growth.

The following year, differences in the response to nitrate were more marked, although roots of the fall-treated trees on April 6, 1934, had 30 per cent more nitrogen than those receiving the spring applications. On each of the four sampling dates (Table I), the leaves on trees receiving nitrate in the spring were higher in nitrogen than the leaves from plots receiving either fall or split applications. The terminal growth was 3 inches longer, with a difference of 0.87 inch necessary for significance. The greater growth in 1934 over 1933 was in part due to the total destruction of the fruit crop as a result of low temperatures during February, 1934.

TABLE I—TERMINAL GROWTH AND TOTAL NITROGEN CONTENT OF LEAVES OF ELBERTA PEACH TREES FOLLOWING FALL AND SPRING APPLICATIONS OF NITROGEN FERTILIZERS

Treatment		Nitrogen as Per cent Fresh Weight							Terminal Growth (Ins.)	
		1933		1934						
		May 15	June 20	May 9	June 20	July 19	Aug. 28	Aver-age	1933	1934*
Check—No N......		0.66	0.80	0.91	0.72	0.67	0.71	0.75	1.3	3.4
Nitrate of Soda	Spring	1.14	1.04	1.29	1.02	1.11	0.96	1.09	7.0	11.1
	Fall	0.95	0.97	1.22	0.96	0.92	0.88	0.99	5.0	8.0
	Split	—	—	1.24	0.85	0.89	0.85	0.96	5.1	8.0
Calcium Cyanamid	Spring	0.91	0.88	1.06	0.91	0.88	0.86	0.93	3.2	6.9
	Fall	0.93	0.99	1.07	0.82	0.84	0.81	0.88	4.7	6.2
	Split	—	—	1.10	0.88	0.88	0.82	0.92	4.8	6.8
Sulfate of Ammonia	Spring	0.92	0.98	1.12	0.90	0.86	0.89	0.94	4.5	7.1
	Fall	—	0.94	1.16	0.86	0.88	0.85	0.94	4.7	7.2
	Split	—	—	—	0.86	0.89	0.88	0.95	4.6	7.3

*Difference for significance =.87 inches.

Following the spring application of cyanamid the trees were slow to respond, resembling more the check trees in appearance than the fall cyanamid plot. The latter appeared almost equal to the fall nitrate of soda plot in vigor. Analyses showed the spring treatment resulted in less nitrogen in the leaves than the fall treatment in May and June, 1933. The terminal growth averaged 3.2 inches, compared with 4.7 inches for the fall treatment. Following split application it averaged 4.8 inches and the check was 1.3 inches (Table I). The following year the spring cyanamid plot proved equal to the split application and surpassed the fall treatment in nitrogen content of the leaves and terminal growth. The difference in growth between spring and fall plots, while not statistically significant, is closely correlated with average nitrogen content of leaves. Very slight injury to the leaves from cyanamid applied in the spring was apparent late in the season of 1934.

Response to sulphate of ammonia was quite uniform, regardless of time of application. During the first summer, the foliage on the spring-treated plot was distinctly lighter green than that of the fall-treated plot, although at the end of the season the difference in terminal growth was slight (Table I). In 1934, also, no treatment was markedly superior to any other in terminal growth or nitrogen content of leaves. As with nitrate of soda and cyanamid, roots of trees receiving sulphate of ammonia in the fall were higher in total nitrogen content than spring-treated roots before the spring application was made, but this condition did not affect subsequent growth except possibly the first year.

The relative lateness of the spring application in this experiment (1 week before bloom) is not considered an important factor in the results. In a test of Belle peach trees in the same orchard, cyanamid

and sulphate of ammonia applied a month earlier in the spring than nitrate of soda produced relatively the same response as the later applications did with Elberta.

Studying the response to a particular nitrogen fertilizer, permissible since the carriers were alternated in plot sequence, with all spring treatments adjoining, all fall treatments together, etc., the three plots making the greatest growth in 1934 were all nitrate of soda treatments; the three next all sulphate of ammonia plots; the three next, cyanamid plots; and last, the check (Table I).

Comparing the average total nitrogen content of the leaves of the plots during the same season, the same ranking is obtained as by comparison of terminal growth. A correlation of $+.987 \pm .0055$ existed between the two measures of response to treatment, twig growth and nitrogen content, indicating that not only was nitrogen content of leaves an accurate measure of vigor, but also that nitrogen was a limiting element of growth in this orchard. The outstanding response occurred in the spring nitrate of soda plot, with growth in 1934 significantly greater than in other treatments. Determination of pH of soil following the fall fertilizer application in 1934 showed the check, nitrate of soda, and spring sulphate of ammonia plots had decreased slightly in acidity, while the fall sulphate of ammonia plot had increased slightly in acidity to a pH of 5.7.

These results are in accord with the findings of Schrader and Auchter (4), where the response of apple trees low in vigor was decidedly greater to nitrate of soda than sulphate of ammonia in the first year of application. In later years of the experiment the differences became less pronounced (5). Davidson and Shive (2), however, have shown that peach trees in sand cultures assimilated more nitrogen from ammonium than from nitrate when the pH was favorable although the greatest growth was obtained with nitrate as the source of nitrogen. They found the most favorable pH for the absorption of ammonium was 6.0. Comparatively, the pH of the soil in the present study was quite favorable for ammonia utilization.

It has been stated that fall fertilized trees were higher in nitrogen content of terminals and roots in the spring than spring fertilized trees. To determine when the nitrogen was absorbed, samples for chemical analysis were taken from previously unfertilized trees which had received 9 pounds of nitrate of soda or an equivalent amount of cyanamid in the fall of 1933. As shown in Table II, the trees were low in nitrogen on October 19, the date of fertilized application. Two months later, December 22, the twigs contained no more nitrogen than the check trees. The roots of fertilized trees, however, practically doubled in nitrogen content in the same period, compared to only a 15 per cent increase in check roots. Thus, large amounts of nitrogen were absorbed by the roots in the late fall with little further change in concentration until spring. No appreciable increase in the nitrogen content of the twigs was noted, however, until April 6, when growth started. Then there was an increase over March 7 from 0.63 to 0.97 per cent with nitrate of soda, and from 0.63 to 0.86 per cent with cyanamid. Meanwhile the nitrogen content of the roots decreased, those fertilized with nitrate of soda showing the greatest de-

TABLE II—TOTAL NITROGEN CONTENT OF ELBERTA PEACH TREES FOLLOWING HEAVY APPLICATIONS OF NITROGEN FERTILIZERS, ON OCTOBER 19, 1933
Expressed in Per cent Fresh Weight

Treatment	Terminal Growth				
	Oct. 19, 1933	Dec. 22, 1933	Jan. 25, 1934	Mar. 7, 1934	April 6, 1934
Check—No N	0.54	0.66	0.65	0.65	0.84
Nitrate of soda	0.54	0.67	0.69	0.63	0.97
Cynamid	0.54	0.65	0.65	0.63	0.86
	Roots				
Check	0.38	0.44	0.42	0.40	0.52
Nitrate of soda	0.38	0.74	0.74	0.82	0.78
Cyanamid	0.38	0.81	0.72	0.88	0.86
	Leaves				
	May 9, 1934	June 20, 1934	July 19, 1934	Aug. 29, 1934	
Check	0.91	0.73	0.75	0.69	—
Nitrate of soda	1.38	1.20	1.20	1.13	—
Cyanamid	1.30	1.10	1.10	1.10	—

crease. These results indicate that although nitrogen was absorbed by the roots in similar amounts from nitrate and from cyanamid fertilizers applied in large amounts in the fall, more nitrogen was found in the leaves, the trees appeared more vigorous, and terminal growth was slightly greater where nitrate was the source of nitrogen.

It thus appears that nitrogen may be absorbed by peach roots in fall and early winter in large amounts, and held there until growth starts, when rapid translocation takes place to the twigs and buds. Aldrich (1) secured identical results with apple trees following fall and winter applications of nitrogen fertilizers. Whether temperature, dormancy, or some other factor is responsible for this condition is a matter of conjecture. Nightingale and Blake (3) have shown that translocation of organic nitrogen from roots to tops of non-dormant peach trees in sand culture at 52 degrees F was very slow in comparison with that at 70 degrees F, although there was little difference in organic nitrogen content of the roots at the two temperatures.

The results of the above investigation indicate that with peach trees low in nitrogen, the greatest response in twig growth and increasing nitrogen content of leaves from fertilization with equivalent amounts of nitrate of soda, cyanamid, or sulphate of ammonia was secured from nitrate of soda applied in the spring, and to a lesser degree from nitrate of soda, sulphate of ammonia, or cyanamid applied in the fall, or in a split application. After the first year, the response of the trees to spring applications of the latter two fertilizers tended to equal that of fall applications. When larger amounts of cyanamid and sulphate of ammonia were used in this orchard, the response was equally as great as with 3 pounds of nitrate of soda.

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Results of Incorporating a Heavy Application of Superphosphate Deeply into an Orchard Soil

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INSTANCES are not lacking in the literature in which investigators of the problem of apple fertilization in this country have announced finding a direct benefit from phosphorous. Yet, aside from those cases in which the influence is an indirect one related to improved cover crops, the evidence in most cases has not been entirely satisfactory.

In 1929, it was found that seven pairs of plots—the trees in each pair being similar as to size, vigor and previous treatment—could be arranged in the Woodman orchard at the New Hampshire Experiment Station. This is a block of mature Baldwin trees, on a rather light soil low in phosphorous. It was determined to treat one of each pear of plots with phosphorous and reserve the other as a control. Soil management and fertilizer tests have been conducted in this orchard since 1908, and it has been described in detail by Gourley (1). Except for a few trees included in the new plots which had formerly been in division rows, the yields of these trees were available over a long period. The arrangements of the plots and average yields for the

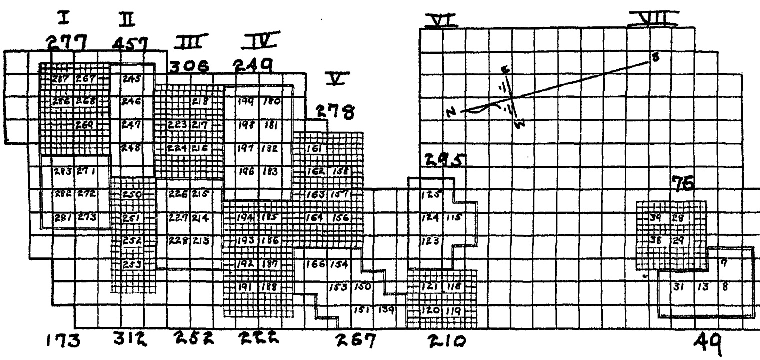

FIG. 1. Woodman Orchard showing seven phosphorus plots (crosshatched), their respective controls and average annual yield per tree (arabic numerals) in each plot for the 10-year period preceding the experiment.

10 years 1919 to 28 are shown in Fig. 1. During this time, yields of the seven phosphorous plots and their respective controls had been on the average nearly equivalent.

In 1908, when the original experiment was begun, duplication or replication of plots had not yet come in vogue. Each of the seven series of new plots therefore had previously been subject to a different treatment. For 20 years, the two plots VIIP and VIIC had been maintained in sod with no fertilizer whatever. These trees were smaller than the others and had produced little. The two plots of series VI had been under cultivation with non-legume cover crops but without any fertilizer. Series IV had been under a cultivation and cover crop system of soil management supplemented by a complete fertilizer

containing 2 pounds of nitrate of soda, 4 pounds of sulphate of potash, and 8½ pounds of superphosphate per tree. The treatments of series I, II, III, and V were identical to IV except as follows: in series I, each tree had had 8 pounds of K_2SO_4 instead of 4; in series II, the quantity of sodium nitrate was 6 pounds instead of 2; in series III, 17 pounds of superphosphate was used instead of 8; in series V, basic slag equivalent in P_2O_5 was used in place of the superphosphate.

Analyses show that on the average the soil in this orchard originally contained only about 1000 pounds of P_2O_5 per acre 8 inches of soil. As indicated above, appreciable amounts had been worked into the soil of some plots during the progress of the original experiment. Assuming that phosphorous in leaves is returned to the soil, no large proportion of this could have been utilized by the trees, and most of it presumably was fixed in the tilled layer or near it. It is possible, therefore, that the plots receiving the smaller amount of phosphorous may in this time have fixed enough P_2O_5 almost to double that originally present. On the same basis, the soil of series III may have by 1928 approached a total of 3000 pounds of P_2O_5 per acre.

Taking this into consideration, in each series except III, 169 pounds of superphosphate was applied to the 35 foot square on which each tree stands. In series III, 254 pounds was used. These amounts were sufficient to increase the P_2O_5 content of the surface 8 inches by at least 50 per cent, and in series VI and VII by 100 per cent or more. Half the fertilizer was plowed in deeply and the remainder put on the surface and disked in. The orchard was then laid down to sod, in order that the roots might thoroughly permeate the area in which the phosphorous had been incorporated. No additional phosphorous has been used but each year 10 pounds of nitrate of soda per tree or its equivalent in other nitrogen carriers has been applied. The experiment then is a comparison of nitrogen plus phosphorous with nitrogen alone in a sod mulch orchard.

In the 6 years since this test was begun, two heavy crops have been harvested, in 1930 and 1933. There was a complete failure due to frost in 1932. The other three have been "off" years. The orchard was seriously injured by the winter of 1933–34, and perhaps yields for 1934 should not be included. They would have been light in any case, and could not have affected the net result materially.

It is to be noted (Fig. 1) that under identical treatment for the period 1919–1928 inclusive, trees on the east side of the orchard had outyielded those on the west side. This probably is due to more favorable drainage conditions. In Table I, the average yield per tree for the period 1929–34 inclusive is arranged by position of plots for ready comparison with Fig. 1. It seems significant that highest yields are no longer found uniformly along the east side. Instead in every case except one the plots treated with phosphorous have highest yields regardless of position. Even in this case, the yield of plot VIP on the west side is more nearly equal to that of VIC at the end than at the beginning of the experiment. On the other hand, two phosphorous plots, IP and IIIP, on the east side, while still leading their respective controls, do not show as much difference as at the outset.

TABLE I—AVERAGE ANNUAL YIELDS PER TREE, 1929–1934, PHOSPHORUS EXPERIMENT (ARRANGED BY LOCATION OF PLOT) (YIELD IN POUNDS)

I P 183	II C 206	III P 173	IV C 128	V P 281	VI C 355	VII P 273
I C 146	II P 237	III C 166	IV P 213	V C 247	VI P 326	VII C 198

P = phosphorus plots C = control plots

With seven replications, a statistical analysis of the data may have some value. The phosphorous plots now show an average annual yield per tree 34 pounds greater than their controls. By Fisher's modification of student's method odds of 19 to 1 are indicated against this large a variation occurring by chance. Incidentally, these odds are no doubt too low. The statistical methods are based on the assumption that gains of all phosphorous over their individual control plots should be uniform. We have seen that first one and then the other has the advantage of position on the east side, and besides the response might well differ owing to differences in previous treatment. Except for variations due to these sources, the odds indicated would have been larger.

That the phosphorous has brought about an increase in yield seems probable, although hardly certain with this set-up. An endeavor to analyze the source of the increase breaks down completely. Terminal growth was not increased. Both per cent bloom and set were higher where phosphorous was used, but differences as indicated in Table II are very small. Size of fruits was not measured.

TABLE II—SUMMARY OF RESULTS, PHOSPHORUS EXPERIMENT

Criterion	Period	Average per Tree N plots	Gain or Loss P plots	P. (from Fisher)
Average annual yield	1933 only	336	76	0.05
Pounds per tree....	1929–1933*	254	44	0.05
	1929–1934*	207	34	0.05
Bloom (per cent)...	1929–1934	18.2	3.7	0.3
Set (per cent)......	1929–1934	28.6	1.0	0.6
Average terminal shoot growth (inches).........	1929–1933	8.4	–.35	0.3

*Exclusive of 1932.

Finally, it may be remarked that even though an increased yield due to the phosphorous fertilizer seems probable, the odds are against the application as a commercial venture. After deducting costs of harvesting and marketing, the extra apples make the purchase of 14,878 pounds of superphosphate a poor gamble, indeed.

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Response to Nitrogen Fertilizers Applied in Different Areas Under Rome Apple Trees

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GROWERS want to know the best place, with reference to the soil area under the tree, to apply nitrogenous fertilizers, so that they will be taken into the tree at the earliest possible time after application, and give the maximum tree response. The existent opinion on this matter has been quite variable. Some growers have favored applying the fertilizer in a narrow ring either close to the tree or at varying distances away from the tree trunk in a narrow band. Others have advocated covering the whole area beneath the limb spread in a uniform coverage. Still others have applied fertilizer just beneath the perimeter of the tree in a circle extending just inside the limb spread, and outward several feet beyond the spread. For various reasons experimental workers generally have favored the latter method, although the experimental evidence to support any of the methods used has been quite negligible.

In the fall of 1930 a two-row block of uniform, 25-year-old Rome apple trees were selected in the Caspar Orchard, at Hancock, Maryland, for the purpose of studying the effect of applications of 10 pounds of sodium nitrate at varying distances from the tree trunk. The 10 pounds of nitrate was applied each fall for 2 years at the following eight different distances from the tree trunk: from trunk to 3 feet; from trunk to 6 feet; from trunk to 9 feet; from trunk to 12 feet; from 3 feet to 6 feet; from 6 to 9 feet; from 9 to 12 feet; and from 12 to 15 feet. The above treatments were replicated at random six times down through two parallel rows of trees. Unfertilized trees were left at the beginning and end of each set of treatments to serve as checks. In all there were 56 treated trees, and 14 check trees. The limb spread on the average was about 11 feet from the trunk.

Methods of measuring responses:—At the time that the first application of $NaNO_3$ was made, trunk circumference measurements were obtained in centimeters to the nearest millimeter, and subsequent measurements were made at about the same time each succeeding year of the experiment. Terminal growth measurements were made in inches, forty major terminals being measured on each tree each year.

Blossom records were obtained by tagging four major limbs about the tree, and counting the individual blossoming and growing points separately. Yield records were obtained by hand picking the fruit, sizing it over a Trescott grader, and counting the number of fruits in a number of bushels of the various sizes separated out.

Results obtained:—The data presented in Table I indicate that measurable responses to nitrogen applications were obtained when applied at any distance from the tree trunk up to 15 feet away from the trunk. The poorest responses were obtained from the 0–3 feet and 3–6 feet applications. With these two treatments the foliage was never as green in color as the others and there was a tendency to lose their foliage early, resembling the check trees in this respect. However, sufficient nitrates evidently were taken up to maintain good tree

growth as indicated by the trunk and terminal measurements shown in Table I. The set of fruit, as indicated by the numbers of fruit harvested from these trees, was somewhat better than the check trees, but not as good as many of the other treatments. Per cent of bloom showed much the same differences.

TABLE I—SHOWING GROWTH RESPONSES OF ROME APPLE TREES RECEIVING 10 POUNDS OF $NaNO_3$ AT VARYING DISTANCES FROM THE TREE TRUNK

Distance of Application from Tree Trunk	Bloom (Per cent)			Number of Fruits Borne per Tree		Terminal Growth (Inches)			Trunk Circumference Increase (Cms)		
	1931	1932	1933	1931	1932	1931	1932	1933	1931	1932	1933
Check (No fertilizer)...	28.6	45.0	22.0	1380	1093	2.8*	2.9	2.9	3.5†	2.2	2.9
0–3 feet..	29.9	75.4	38.5	1744	2399	3.05	3.9	4.0	4.5	2.7	3.3
0–6 feet..	25.9	74.5	57.1	2153	3001	3.22	4.22	4.2	4.6	2.6	3.0
0–9 feet..	35.9	91.3	65.7	1980	2772	3.5	4.07	4.1	4.4	2.5	3.2
0–12 feet.	27.4	84.0	68.5	2099	2532	3.47	3.95	4.0	4.7	2.5	3.2
3–6 feet..	29.8	53.3	50.7	1960	2043	3.41	4.5	4.5	3.7	2.8	3.1
6–9 feet..	22.6	77.8	75.5	1718	2723	3.27	4.3	4.1	4.9	2.1	3.2
9–12 feet.	31.0	70.1	50.1	1942	2361	3.41	4.21	4.2	4.2	2.0	3.0
12–15 feet	22.6	74.0	73.0	2981	3606	3.33	4.5	4.3	4.9	2.7	3.3

*Differences greater than .43 inches give odds of 19:1 by Fisher's Analysis of Variance.
†Differences greater than .71 cms. give odds of 19:1 by Fisher's Analysis of Variance.

With few exceptions the nitrates applied gave significantly better terminal growth and fruiting responses than the check trees, receiving no additional nitrates, irrespective of where the nitrogen had been applied, either under the tree or extending beyond the limb spread 3 feet.

Comparisons of growth responses among nitrogen treatments possibly are complicated by differential effects of fruiting, since heavy fruiting would no doubt result in decreased growth response as indicated by the data obtained.

Those trees which had received the nitrates from 12 to 15 feet away from the tree trunk showed the greatest actual yield of fruit at harvest time, despite the fact that the bloom on these trees was somewhat less. The fall application of fertilizer in 1930 did not affect the percentage of blossoms in 1931, as it had been applied after differentiation of fruit buds had taken place.

Summary and conclusions:—The results obtained in this experiment indicate that better responses to 10 pounds per tree nitrogen applied to apple trees might be expected when such applications are spread over a wide area rather than in concentrated areas close to the tree trunk. The best fruiting responses to nitrates were obtained when the nitrates had been applied just outside the spread of the branches. It is possible that some root injury might accrue from heavy applications in closely confined areas near the tree trunk; however, such injury was not observed on the large trees used in this experiment, although fruiting of such trees was poorer than the wider applications.

The effect of heavy fruit set on trees receiving the wide spread applications and the poorer set of fruit when the nitrate was applied close to the tree trunk, might possibly account for some of the equalizing effect on trunk circumference increases found in this experiment.

Some root studies on Stayman trees adjacent to this experiment, showed that the larger proportion of fibrous roots in the upper foot of soil were found at the greater distances from the tree trunk. If Rome roots were similarly distributed in this soil, it might be logical to expect better tree responses from nitrogen applications in the outer areas, as was the case. The root studies are reported in another paper in this issue of the proceedings.

Acknowledgments

Grateful acknowledgments are extended to Dr. E. C. Auchter, who initiated this study, and to Dr. A. Lee Schrader for corrections in the manuscript.

Effects of Fall and Spring Applications of Various Nitrogen Fertilizers on Fruit Trees

By A. L. SCHRADER, *University of Maryland, College Park, Md.*

ABSTRACT

This material will appear as a bulletin from the Maryland Agricultural Experiment Station.

Additional Studies on the Effect of Commercial Forms of Nitrogenous Fertilizers as Applied to Apple Trees

By R. S. MARSH, *University of Illinois, Urbana, Ill.*

ABSTRACT

This paper will constitute part of the material which is to be published in a bulletin from the Illinois Agricultural Experiment Station.

FROM the analysis of young apple trees that had been fertilized with ammonium sulfate, there seemed to be an earlier mobilization of nitrogen in those treated during the previous fall as compared to the spring-fertilized block. This was shown by the greater amount of total nitrogen in the previous season's growth on the fall-treated trees as compared to the spring-fertilized trees, while the reverse was true when the total nitrogen of the root system of the two blocks was compared.

Calcium cyanamid treated trees showed no differences from the checks except that soil nitrates were higher in the cyanamid blocks during September and October than in the check blocks or blocks receiving other forms of commercial nitrogenous fertilizers.

The Storage Behavior of Apples as Influenced by Nitrogen Fertilization and Storage Temperatures

By H. H. PLAGGE, *Iowa State College, Ames, Ia.*

ABSTRACT

This paper is to appear in the Journal of Science of the Iowa State College.

Photosynthesis in Apple Leaves During Late Fall and Its Significance in Annual Bearing

By A. J. Heinicke, *Cornell University, Ithaca, N. Y.*

UNDER many orchard conditions the foliage of mature trees shows a gradual loss of green color during several weeks to a month or more prior to leaf fall. This change in color is associated with an accumulation of carbohydrates in the leaves and the migration of mineral nutrients back to the woody tissue (5). All these manifestations of senility and of approaching abscission may be delayed by applications of nitrogenous fertilizers in late summer, a month or more after shoot growth has ceased, when the growing points are not easily forced from their rest. The foliage may thus be kept dark green and attached to the tree until frozen.

To what extent do the leaves function in carbohydrate synthesis during the month or so preceding abscission, and how much more efficient in this respect is the foliage "rejuvenated" or kept dark green by fall application of nitrogen? How may the tree benefit from the additional carbohydrates manufactured in late fall?

Previous studies have shown that the rate of photosynthesis of apple leaves during the main part of the growing season is markedly influenced by their color (3). The darker green the leaf surface, other factors being favorable, the more carbohydrates are manufactured. The data in Table I substantiated by other experiments, indicate clearly that the rate of photosynthesis of the foliage which is beginning to lose its dark green color may be increased by nitrogen application during the latter part of the growing season.

The trees used in this case were healthy specimens of the variety McIntosh, 6 years old, growing in grass. The photosynthesis was determined by the method described elsewhere (3). After a preliminary run of 12 days (Series 1) to determine the relative rate of carbon dioxide assimilation of two lots of leaves on similar untreated trees, an application of nitrogen was made to one tree of the pair, while the other continued as a check. The leaves on the fertilized tree became darker green within a few weeks. Several additional 12-day series of determinations were subsequently made.

With respect to their average rate of photosynthesis, the two lots were fairly comparable to begin with. Lot A responded to the fertilizer by increased CO_2 assimilation soon after it was applied, and the dark green leaves showed a very high average rate as late as the third week in October, even though the mean temperature was relatively low. The foliage on the fertilized tree continued to manufacture carbohydrates in excess of respiration during the last week in October and early November. During this same period the yellowish leaves on the untreated Lot B failed to assimilate as much CO_2 as they respired. The rate of photosynthesis of individual leaves on all trees was definitely related to the intensity of green color, in accordance with previous results. The marked drop in photosynthesis in both lots after October 22 was associated with a rapid loss of green color. Other nearby fertilized trees retained the dark green foliage until the freeze of November 4.

TABLE I—APPARENT PHOTOSYNTHESIS IN LEAVES OF McINTOSH APPLES

Series	Interval 1934	Mean Temp. (Degrees C)	Average Rate of Photosynthesis* ($MgCO_2Hr100\ Cm^2$)		Total CO_2 Assimilated in Excess of Daytime Respiration Mg 100 Cm^2 for Interval†	
			Lot A	*Lot B*	*Lot A*	*Lot B*
1	July 24–Aug. 4	22.2	10.6 Ck.	9.8 Ck.	1018 Ck.	940 Ck.
2	Aug. 22–Sept. 1	20.4	12.8+N‡	9.9 Ck.	1229+N	950 Ck.
Av. 2+3	Aug. 22–Oct. 22	18.4	15.3+N	8.9 Ck.	4774+N	2779 Ck.
3	Oct. 11–Oct. 22	11.1	17.7+N	7.9 Ck.	1274+N	569 Ck.
4	Oct. 23–Nov. 3	9.1	7.2+N	−1.2 Ck.	518+N	−86 Ck.
2+3+4	Aug. 22–Nov. 3	—	—		7795+N	4212 Ck.

*Average based on determinations with 4 leaves in all cases. In Series 1 and 2, a 4-hour run in the morning and in the afternoon was made each day; in Series 3 and 4 each day's run lasted 6 hours, from 9 a.m. to 3 p.m.
†Calculated on the basis of an 8-hour day for Series 1 and 2; and for a 6-hour day for Series 3 and 4.
‡3 pounds Ammonium sulphate applied Aug. 4, 1934.

Even though the tree chosen for determination of photosynthesis probably did not show the highest degree of response to the nitrogen application, nevertheless a given area of its foliage accounted for almost twice as much CO_2 assimilation from August 22 to November 3 as compared to the untreated tree. Furthermore, the latter lost most of its leaves before the experiment was concluded, while the former retained at least two-thirds of its foliage.

The significance of the difference in rate of photosynthesis by the two lots of trees may be appreciated the better if we think in terms of an individual apple spur. A moderately vigorous spur has at least 100 square cm of leaf surface. The total dry weight in a dormant flower bud and in 2 cm of spur growth averages about 64 mg per spur. This would contain approximately 27 mg of carbon. It takes just about 100 mg of CO_2 to furnish the 27 mg of C found in a vigorous spur. Obviously, if there is no fruit to be matured, much of the extra carbohydrates produced in fall by trees with dark green leaves are stored elsewhere in the tree, or used for root growth.

It is evident that the foliage which functions more efficiently in late fall increases the carbohydrate reserves of the stem tissues above the usual amount. This is indicated for starch by the iodine test. Such extra reserves are an important factor in the development of a large leaf surface per inch of shoot or spur growth early the next spring(2). Water, nitrogen, and other nutrients, of course, are also needed by the expanding leaves but these can usually be provided more readily than can the carbohydrate reserves. The larger the leaf surface per inch of shoot growth the more carbohydrates can be manufactured for subsequent growth and storage.

The development of a large early leaf surface is especially important as a means of bringing about regular bearing in many varieties of apple. In trees that have formed a large percentage of fruit buds during the non-fruiting year, much of the reserve food is used by the opening flowers the following spring (6). With this competition for reserve food the initial leaf surface is often too small to meet the early

season's growth requirements for photosynthetic products and at the same time provide for the accumulation of carbohydrates associated with the initiation of next year's flower buds. Without the possibility of manufacturing carbohydrates in excess of current needs relatively little could be accomplished by thinning the fruit, and the extra heavy spring application of nitrogen fertilizer in such cases would hardly bring about conditions more favorable for early accumulation of reserves. If a leaf-fruit ratio suitable for maturing perfect apples and also for influencing flower bud initiation is to be provided by a degree of thinning which does not involve too large a reduction in the current year's crop, there must be present a large leaf surface developed early in the season.

If the leaf surface is to be effective in bringing about accumulation of reserves early in the season it must of necessity be produced mainly on spurs or relatively short shoots, and the individual leaves must be larger than normal. This requires an abundance of reserve food, which in turn may be provided by keeping the foliage healthy and dark green the preceding season after shoot growth has stopped. It is especially important if alternate bearing is to be influenced to keep the foliage functioning efficiently in photosynthesis during late summer and early fall in the off or light crop year.

Studies to be reported in detail elsewhere indicate that root growth during the fall is very much greater in the trees whose leaves remain dark green and active longest. Relatively little growth is made after leaf fall. The larger the root system the more water and nutrients may be obtained from the soil in spring. This is important, along with the food reserves, for the development of a large early leaf surface (2).

Exposure of apple branches to 0 degrees F beginning November 10, 1934, suggests that the early winter hardiness of the woody tissues of the tree was increased in those cases in which the late summer nitrogen application caused the leaves to remain dark green until finally frozen. It should be emphasized that in these experiments the nitrogen was applied a month or more after the growing points had entered their rest period so they could not easily be forced into further activity. The only visible response to the fertilizer was the darker green foliage and the delay in leaf fall.

Where the fertilizer application causes the shoot growth to continue until late in the season, the hardiness of the tree would be greatly reduced on account of immaturity of the tissues. If applied shortly before or after leaf fall, the benefits of nitrogenous fertilizer materials are largely confined to meeting the needs for nitrogen early next spring. To derive the greatest benefits, the application should be made late enough in the summer so there is no danger of forming a second growth, but soon enough to increase the photosynthetic activity of the foliage or to maintain it at a high level during the two or more months preceding leaf fall.

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Photosynthetic Activity and Internal Structure of Apple Leaves are Correlated[1]

By Wm. F. Pickett, *Kansas Agricultural Experiment Station, Manhattan, Kan.*

THIS is a report of an experiment designed to determine whether the structure of the mesophyll of an apple leaf might be one of the factors which modify the rate of photosynthesis. The characteristics of the apple leaf mesophyll of interest in this study were the extent of the intercellular spaces as judged by their cross sectional area measurements and perimeter measurements.

Methods and Materials

The two varieties selected for this study were Livland and Delicious. These were chosen because, in a similar anatomical study in 1933, the author found that they possessed greater difference in the extent of intercellular spaces in the mesophyll than any other varieties studied (1).

Two classes of leaves of each variety were used *viz,* greenhouse grown and orchard grown. In January, 1934, several 1-year-old whips of the two varieties were planted in 12-inch clay pots and placed in a greenhouse. In July, 1934, these trees were taken to the orchard of the Experiment Station at Manhattan, and the pots were plunged in the orchard soil for a few days to bring the soil moisture in the pots to approximately the same per cent as that in the soil outside the pots. The photosynthetic determinations of the greenhouse grown trees could then be made under the same environmental conditions as the orchard trees.

The trees grown in the greenhouse were divided into two groups. One group of 9 trees of each variety was placed in a house where the day temperatures were kept from 65 to 75 degrees F and night temperatures were seldom below 45 degrees. The other group of 9 trees of each variety was placed in a house where the day temperatures ranged from 95 to 110 degrees F and the night minimum temperatures were usually about 70 degrees. The trees in the cooler house grew much more satisfactorily than those in the warmer house, and were used in the study herein reported.

In order to obtain the measurements of the intercellular spaces in the mesophyll, mounts of cross sections of mature leaves were prepared on microscope slides. These leaves were taken from shoots on the south side of the outer periphery of the trees. The slides were mounted on a microscope, so arranged with an electric spot light that it served as a microprojector. This procedure is described in a paper presented before this society a year ago.

The rate of apparent photosynthesis was judged by the modified Sachs punch method. Discs one square centimeter in area were punched from 50 mature leaves, one disc being removed from each leaf at 6:00 a. m., another at 2:30 p. m., a third at 6:00 a. m. the second day. The first and second discs were punched from opposite

[1]Contribution No. 129. Department of Horticulture.

sides of and near the midrib. The third was taken just below the first. In each instance no large lateral vein was severed in removing the disc, although it was impossible to avoid the smaller veins. The leaves used were located on new shoot growth, those on spurs were not sampled.

The discs were placed in glass vials and weighed, placed in an electric oven at a temperature of 65 degrees C for an hour and then dried at a temperature of 98 degrees C and weighed again. The gain in dry weight from 6:00 a. m. to 2:30 p. m. gives an index of the net gain in carbohydrates over those used in respiration and translocation. The loss in dry weight from 2:30 p. m. until 6:00 a. m. the second morning gives some indication of the amount of carbohydrates lost by respiration and translocation from the leaves. These indices are subject to certain criticism in that the gain in dry weight per unit of leaf surface during the day includes the ash accumulation as well as protein gain.

One additional objection to the punch method of measuring apparent photosynthesis is that if the leaves shrink during the day as a result of the loss of water, the punches in the afternoon would not be comparable in leaf area to those removed in the morning. This criticism does not apply to these tests since the leaves did not shrink in area during the day. This was determined by measurements of leaf blade widths of a set of leaves made during both the morning and the afternoon periods.

Without doubt the removal of several discs from a leaf as small as an apple leaf gives rise to certain enzymatic disturbances which materially affect the normal metabolism of the leaf. Nevertheless the treat-

TABLE I—Variation in Dry Matter of Apple Leaves

Time and Date 1934	Dry Weight per M^2 Leaf Area (Gms)	Gain or Loss in Dry Matter per M^2 Leaf Area (Gms)	Total Gain in Dry Matter per M^2 Leaf Area (Gms)	Water in Leaves (Per cent)
		Livland, grown in orchard		
6:00 a.m., July 31...	91.60	—	—	55.12
2:30 p.m., July 31...	97.53	+5.93	—	54.80
6:00 a.m., Aug. 1...	93.15	−4.38	10.31	57.31
		Livland grown in greenhouse		
6:00 a.m., July 31...	85.24	—	—	55.17
2:30 p.m., July 31...	88.72	+3.48	—	54.94
6:00 a.m., Aug. 1...	87.26	−1.46	4.94	57.09
		Delicious grown in orchard		
6:00 a.m., July 31...	85.46	—	—	55.21
2:30 p.m., July 31...	90.14	+4.68	—	53.48
6:00 a.m., Aug. 1...	87.70	−2.44	7.12	54.80
		Delicious grown in Greenhouse		
6:00 a.m., July 31...	77.14	—	—	56.26
2:30 p.m., July 31..	79.02	+1.88	—	54.05
6:00 a.m., Aug. 1...	76.72	−2.30	4.18	55.95

Temperatures: 6:00 a.m. July 31, 73 degrees F, relative humidity 42 per cent.
2:30 p.m. July 31, 100 degrees F, relative humidity 21 per cent.
6:00 a.m. Aug. 1, 82 degrees F, relative humidity 37 per cent.
July 31 was cloudy, practically no direct sunlight at any time during the day.

ment of the leaves under consideration was uniform and the results are comparable. Livland leaves are larger than Delicious leaves, the average area being 6.53 ± 1.53 square inches for the Livland and 3.41 ± 0.65 square inches for the Delicious.

Results of Study

In Table I, data are presented to show the gains and losses in dry weight per square meter of leaf area from 6:00 a. m. July 31, to 6:00 a. m. August 1. These hours were selected because previous trials had shown that there was no measurable gain in dry matter before 6:00 a. m., that the gain in dry matter occurred between 6:00 a. m. and 2:30 p. m., and that beginning about 2:30 in the afternoon the amount of dry matter per unit of leaf area became smaller. Assuming that the amount of photosynthate lost by the leaf in the processes of translocation and respiration between the hours of 2:30 p. m. and 6:00 a. m. would be the same as that used by these activities between 6:00 a. m. and 2:30 p. m., the sum of the day gain and afternoon and night loss in dry matter would represent the total amount of photosynthate manufactured during the day.

These data show that the orchard grown Livland leaves made a net gain of 5.93 gms in dry matter per square meter of leaf area during the day. The Delicious leaves from orchard trees made a net day gain of 4.68 gms in dry matter.

The greenhouse grown Livland leaves assimulated a net day gain of 3.48 gms dry matter per square meter of leaf area and the greenhouse grown Delicious leaves had a gain of 1.88 gms.

The four groups of leaves rank as follows in the net day gains in dry weight. (1) orchard grown Livland, (2) orchard grown Delicious, (3) greenhouse grown Livland, and, (4) greenhouse grown Delicious. The same ranking applies to the measurements of the intercellular spaces in the mesophyll as shown in Table II.

The cross sectional area measurements were made because it was believed that these data have a relationship with the exposed surface area of the cells bordering the intercellular spaces. The intercellular spaces are more or less spherical in shape, and the area of the surface of a sphere is a function of its diameter, which may be determined if a series of cross sections is measured. There is a close relationship between the area of the intercellular spaces exposed when a leaf is cut transversely and the perimeters of these spaces. This ratio varies from 2.018 to 2.19 with the samples represented in Table II.

TABLE II—Intercellular Measurements—Apple Leaf Mesophyll

Variety	Place Grown	Area[1] (Sq Cm)	Perimeter[1] (Cm)
Livland	Orchard	0.11990	0.2362
Livland	Greenhouse	0.07045	0.1429
Delicious	Orchard	0.09660	0.1949
Delicious	Greenhouse	0.06715	0.1369

[1]Measurements of each variety were made from 50 projected images 27.92 cm long at a magnification of ×900, so that a plainimeter and a chartometer could be used conveniently. The data in the table however, represent the actual area or perimeter measurements, per lineal centimeter of cross sections of the leaves, at natural size.

These apparent photosynthetic activity records are much lower than some investigators report for other species of plants. This experiment was started on the last day of July, 1934, a month which broke all records at Manhattan for the past 75 years for high temperatures of any month. On twenty-six days the maximum temperature was 100 degrees F or higher and during eleven consecutive days the maximum reading was 111 degrees or higher. The rainfall for the month was 0.86 inch, and at the time of this experiment the average moisture content of the top first, second, and third foot samples of soil was 11.6 per cent, dry weight basis. Many trees in the orchard were wilted but the ones used in this test of July 31 to August 1, were apparently turgid.

Stomatal behavior was observed on July 18, 1934, and not any stomata were open after 6 a. m. These determinations were made by tearing off a small section of the lower epidermis of the leaf and quickly plunging it in absolute alsohol, after which the strips were examined under a microscope. The leaves, however, carried on some apparent photosynthetic activity. As judged by the leaf punches, Delicious leaves gained 1.12 gms dry weight per square meter of leaf area between 6:00 a. m. and 2:30 p. m. and Livland gained 1.22 gms. Determinations of total acid hydrolyzable carbohydrates expressed as dextrose were made on leaves from these same Delicious and Livland trees. Between the hours of 6:00 a. m. and 2:30 p. m. the Delicious gained 0.22 gm of these carbohydrates per square meter of leaf area and Livland gained 1.39 gms.

Repeated trials using the modified Sachs method in studying apple leaf activities show that there is a fairly close correlation between night temperatures and the amount of dry matter lost by the leaves between the hours of 2:30 p. m. and 6:00 a. m.,—there being greater losses on warm nights than on cool nights.

During the summer of 1934, samples were collected from orchard grown Livland and Delicious leaves on 20 days to determine the apparent rate of photosynthesis by the modified Sachs punch method. On 11 of these days, Livland made a heavier gain during the day in dry weight, per square meter of leaf area, on 8 days Delicious made the greater gain, and on 1 day the gain was the same for both varieties.

None of the trees represented in Table I had fruit on them. The presence of fruit on a branch influences the photosynthetic activities of nearby leaves. No fruit set on the Livland trees in 1934. Many other Delicious trees set good crops of fruit. On six different days the photosynthetic activity of leaves on Delicious trees bearing fruit was compared with that of Delicious foliage on trees with no fruit and on every occasion the leaf punches from the trees with fruit showed a greater dry weight accumulation during the day than those from trees without fruit.

Discussion

Under the conditions described for this experiment, orchard grown Livland apple leaf mesophyll has greater intercellular space than greenhouse grown Livland leaves. Similar differences exist with

Delicious foliage. Orchard grown Livland leaves have more extensive intercellular spaces than orchard grown Delicious leaves and apparently these differences are reflected in the photosynthetic behavior of the two varieties. Likewise the more open mesophyll of the orchard grown leaves may be one of the contributing factors in enabling them to be more active in carbon assimilation than the greenhouse grown leaves. Several factors enter into and govern the rate of photosynthetic activity of green leaves, and the extent of the surfaces of the exposed cell walls bordering the intercellular spaces is probably one of them.

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The Intensity of Light Striking Leaves of Apple Trees at Different Times of Day

By E. P. CHRISTOPHER, *Rhode Island State College, Kingston, R. I.*[1]

INVESTIGATORS of photosynthesis have studied especially the influence of three external conditions: light, temperature, and the carbon dioxide supply of the air. Blackman and Matthaei (1) early presented their findings in the form of a theory of optima and limiting factors. Kostytschew (4) in discussing some of his results, although questioning that the three before mentioned factors are responsible for all variation in photosynthetic activity, points out that light is often limiting. Heinicke and Hoffman (3) suggest that a mean light intensity above 1500 foot candles would support maximum photosynthesis if other conditions are favorable. They state that this amount of light would be available to leaves in the shade on the north side of an apple tree on clear days. The author (2) found the CO_2 assimilation of leaves on the southeast side of a Baldwin apple tree to be, on the average, greater than that of leaves on the west or northwest side. Occasional readings, using a Weston illuminometer, indicated a tremendous variation in the light intensity striking different leaves, the leaves on the southeast side averaging a higher light intensity.

The importance of light as a factor in photosynthesis and the variation in light available to different leaves as indicated in the author's (4) previous work, suggested a detailed study of the light intensity striking leaves at different times of day. This is the first of a series of studies which, it is planned, will take account of the different seasons of the year. A Weston illuminometer was used. This instrument measures light intensity in foot candles from 0 to 10,000. Light intensity on a very bright, clear day in summer will reach slightly above 10,000 foot candles.

The light intensity striking a given "leaf position" was measured at 15-minute intervals from daybreak until dark. Five leaf positions were considered on the east, south, west, and north sides of a 25-year-old McIntosh tree in the College orchard at Kingston, Rhode Island. Position 1 on the south side of the tree faced south but tilted back into the tree so as to make an angle of 30 degrees with the horizontal. Position 2 faced west and pointed east at an angle of 30 degrees above horizontal. Position 3 faced east and pointed west at an angle of 30 degrees above horizontal. Position 4 faced and pointed south at an angle of 60 degrees below horizontal. Position 5 was a horizontal position. A wooden frame was built so that the positions were rigid and the same at each reading. All leaf bases originated within a 6-inch circle 4 feet above ground and 3 feet in toward the center of the tree. Readings were begun on the east side. Readings for positions 1 through 5 were obtained and then similar readings made in rotation on the south, west, and north sides of the tree. A maximum light reading was taken after the 5th position reading on the south side of the tree. Making

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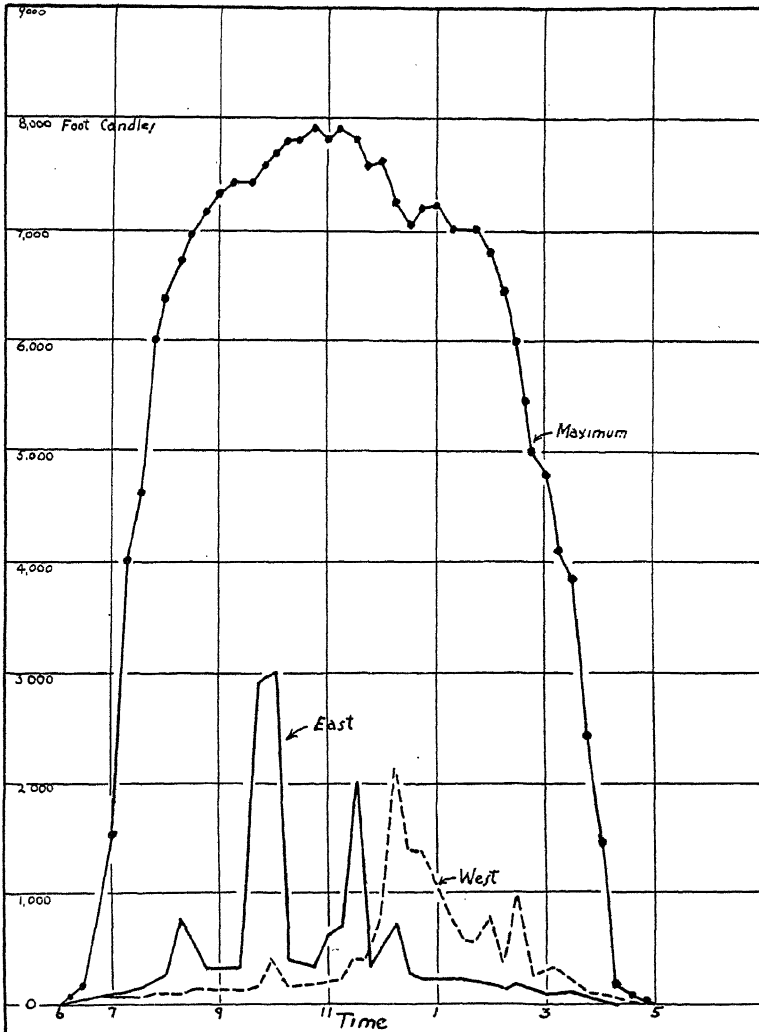

FIG. 1. The course of the light intensity striking leaf No. 5 on the east and west sides of the tree compared with the maximum light recorded. (in foot candles)

the 21 readings took about 7 minutes. Data were taken between October 31, 1934 and November 3, 1934 to include both clear and cloudy weather. Around 3000 readings were taken. The data here presented were taken on November 3, 1934, at which time leaves were still on the tree in sufficient number to offer the usual shading encountered in a well pruned tree.

The weather was bright and clear. The first reading at 6:00 a. m. for all leaf positions, hereafter referred to as leaves, was less than 2 foot candles. A maximum light intensity of 3 foot candles was recorded. A maximum intensity of 58, 140, and 300 foot candles was recorded up to the 7:00 a. m. reading, at which time the sun appeared

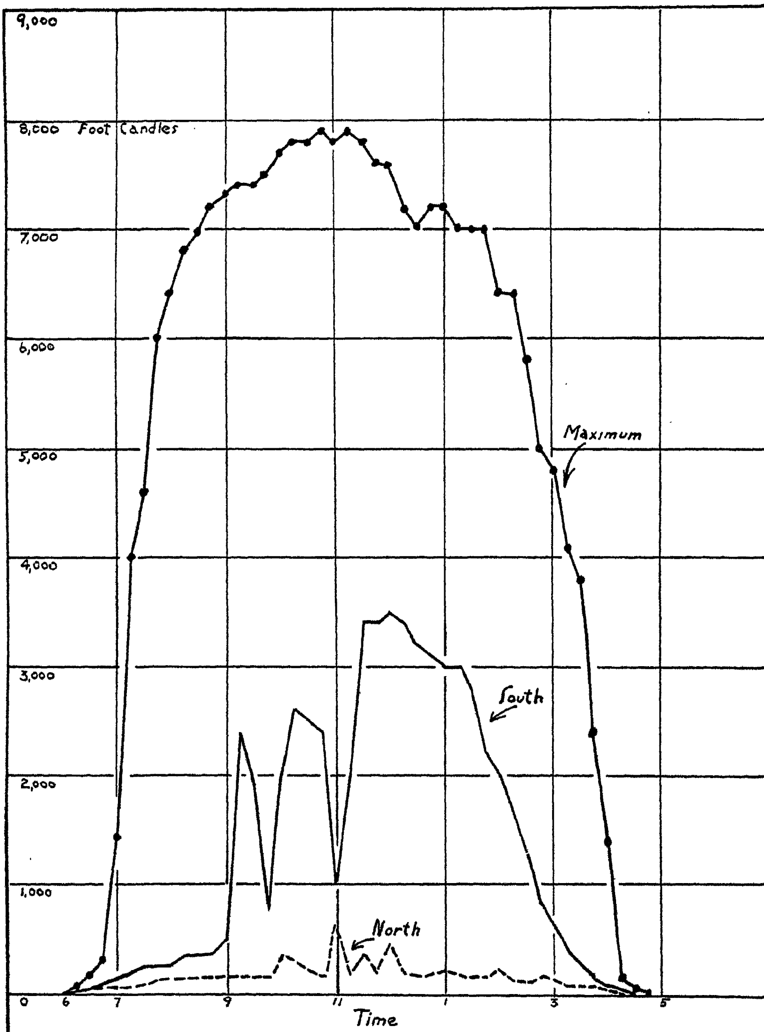

FIG. 2. The course of the light intensity striking leaf No. 5 on the north and south sides of the tree compared with the maximum light recorded. (in foot candles)

above the horizon and the intensity jumped to 1400 foot candles at 7:15 a. m. The highest intensity recorded was 7900 at 10:45 and at 11:15 a. m. This was somewhat below the maximum obtained in the summer, but about as high as can be expected so late in the season. The light intensity stayed above 5000 foot candles from 7:45 a. m. to 2:45 p. m. and above 1400 foot candles from 7:00 a. m. to 4:00 p m. —a period of 9 hours. The intensity dropped rapidly after 4:00 p. m., standing at 160, 40, 16, and 2 for the succeeding readings ending at 5:00 p. m. The sun set at 4:40 p. m.

A great difference in the amount of light striking different leaves was recorded. Fig. 1 has been prepared to show the light intensity striking leaf No. 5 (horizontal position) on the east and west sides of the tree compared with the maximum light recorded. As might be expected, the chart shows that the leaf on the east side received most of its light in the forenoon and the leaf on the west side received more in the afternoon. It is surprising, however, to find that the light intensity was so low, being far below the 1500 foot candles mentioned by Heinicke and Hoffman (5) most of the time, and averaging only 392 foot candles on the east side and 362 foot candles on the west. A great many leaves are in a horizontal position. In mid-summer, when the sun is higher, the intensity of light striking a horizontal plane would, of course, be greater. However, position 4, (facing out and

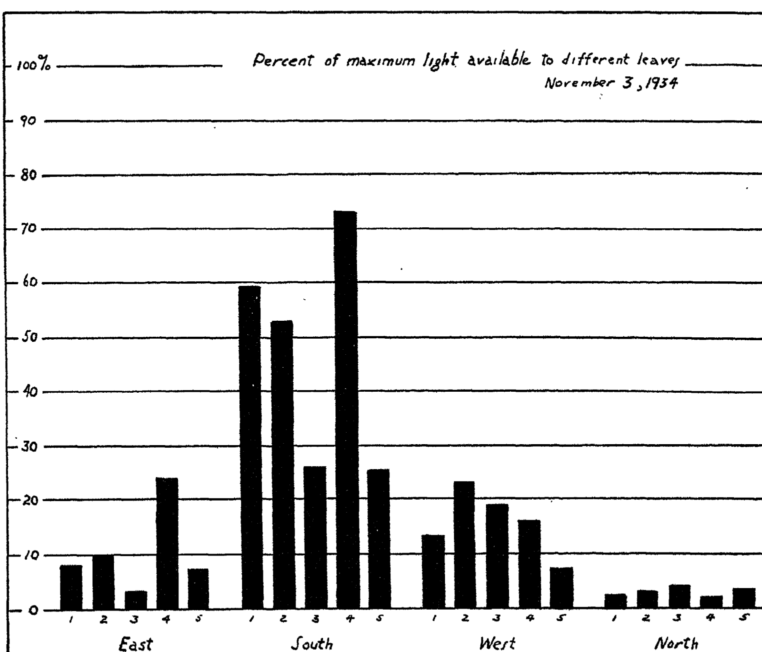

FIG. 3. The percentage of the total available light received by leaves in different positions.

down at an angle of 60 degrees below horizontal) perhaps the most favorably located from the standpoint of angle and freedom from obstruction, averaged only 1256 foot candles on the east side and 846 foot candles on the west side.

Fig. 2 shows the light intensity striking leaf No. 5 on the north and south sides of the tree. Only once did the meter record an intensity of over 500 foot candles on the north side. Light intensity on the south side reached 3500 foot candles and was above 1500 foot candles most of the time from 9:15 a. m. to 2:15 p. m. or less than one-half of the day. The average intensity for the 11-hour period was 1331 foot candles, on the south side, and only 153 foot candles on the north side. At this time of year, the average intensity on the north side was never greater than the 190 foot candles recorded for leaf No. 3 (pointing east and facing west). It would appear that late in the fall when these data were taken light was a limiting factor most of the day for all leaves except those on the south side of the tree. In this instance, the amount of light was greatest in the afternoon for leaf No. 5 on the south side. The irregular curve was caused by the shading effect of other leaves.

Fig. 3 has been prepared to show the percentage of the total available light received by leaves in different positions. It will be noted that leaves Nos. 1, 2, 3, and 5 on the east side received no more than

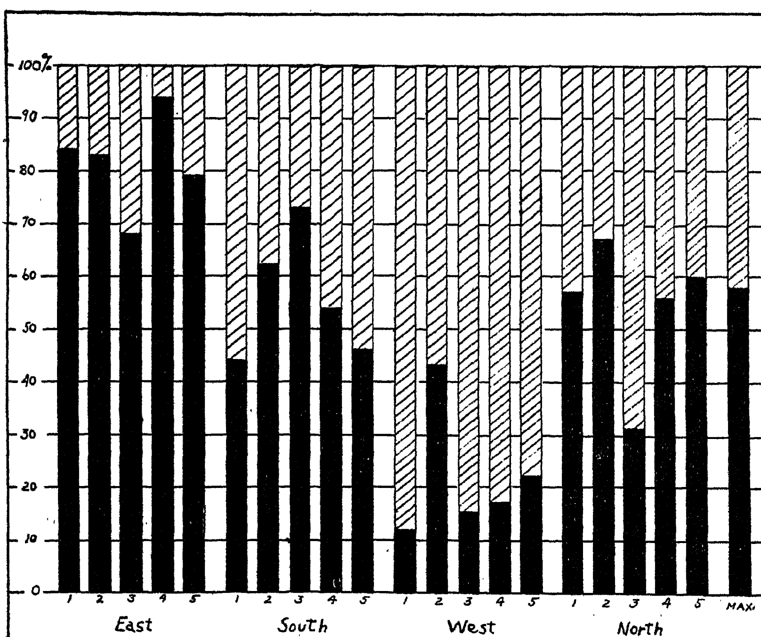

FIG. 4. The percentage of the total light received by a leaf which reached it before and after noon, compared with the maximum light recorded.

10 per cent of the total light, and that leaf No. 4 received less than one-fourth of the total. Leaves on the south side were able to use a much larger percentage; leaves Nos. 1, 2, and 4 received over one-half, and the other two about one-fourth of the total. Leaves on the west side received less than one-fifth of the total available light, except for leaf No. 2 which received 23 per cent. No leaf on the north side received more than 4 per cent of the total light for the day. Even though the daily total be increased considerably, as would be the case on a clear day in summer, the chance of leaves on the north side receiving very high intensities seems slight.

Fig. 4 shows the percentage of the total light received by a leaf which reached it from 7:00 a. m. to 11:45 a. m. and the percentage of the total which reached it from 12:00 m. to 4:45 p. m. The periods were of different lengths and this should be taken into account when considering the data. It will be noted that on the average over 80 per cent of the light to leaves on the east side came before noon. Slightly over one-half (56 per cent) of the light which struck leaves on the south side came before noon, or almost the same proportion as of the maximum light (58 per cent). Only about 22 per cent of the total quota of daily illumination reached leaves on the west side during the forenoon. About 54 per cent of the low daily quota for the north side reached the leaves before noon. Depending as they do on reflected light, only leaf No. 3, facing east, failed to get a rather even distribution of light. In most instances the intensity was less than 200 foot candles, however.

The total "foot candle hours" reaching different positions is presented in Table I.

TABLE I—"Foot Candle Hours" Reaching Different Positions

Position	East	South	West	North	Maximum
1. Pointing back into tree at angle of 30 degrees above horizontal	4,560	34,377	7,459	1,254	——
2. Pointing right (if facing tree) at angle of 30 degrees above horizontal	6,386	15,756	1,349	1,573	——
3. Pointing left (if facing tree) at angle of 30 degrees above horizontal	1,803	14,904	11,001	2,088	——
4. Pointing out at angle of 60 degrees below horizontal	13,813	42,588	9,290	1,420	——
5. Horizontal	4,310	14,637	3,981	1,688	58,317
Average	6,174	24,452	6,616	1,605	——

It will be noted that leaves on the north side of the tree received on the average only about 1600 foot candles in the course of an 11-hour day. Light was indeed limiting to photosynthetic activity if the hourly intensity of 1500 foot candles assumed by Heinicke and Hoffman (3) is necessary. Leaves on the east side received on the average 6174 foot candles or about 4 hours of the minimum intensity for optimum CO_2 assimilation mentioned above. Leaves on the south side on the same basis received enough light for over 16 hours assimilation if it were

evenly distributed at the rate of 1500 foot candles per hour. Leaves on the west side averaged enough light in a day for slightly over 4 hours of optimum activity.

These data indicate that many of the leaves on an apple tree of bearing age receive very low light intensities in the late fall. Measurements at other times of the year would seem desirable and plans are being made to secure them. It may be that light is a seriously limiting factor to photosynthesis in orchards, especially where pruning is neglected.

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The Effect of Spraying Apple Leaves with Certain Less Used Materials Upon Their Carbon Dioxide Intake[1]

By E. L. OVERHOLSER and F. L. OVERLEY, *State College of Washington, Pullman, Wash.*

IN their efforts to employ spray materials that will lessen the lead residue load on apples, the entomologists (2) have in recent years employed calcium arsenate with certain buffers in place of lead arsenate. While the entomologists have been primarily interested in the codling moth control, the horticulturists have been interested in the possible effect of such spray materials upon the foliage. Studies were, therefore, made upon the effect of sprays of calcium arsenate with buffers upon the carbon dioxide intake of Jonathan apple leaves.

METHODS AND MATERIALS

The method of Heinicke and Hoffman (1) was used, the absorption chambers being of the cellophane envelope type. Jonathan trees, 1 year old, growing in pots in the greenhouse were used, as well as trees in the Experimental Orchard in Wenatchee. Since the data under orchard conditions largely substantiate those in the greenhouse, only the latter are presented. Leaves of approximately the same size and exposure were selected.

In the greenhouse, the sprays were applied with a power-driven atomizer type of sprayer, from 16 to 20 hours before the first determination following each spray. Successive determinations were made at 4-day intervals. Successive sprays were applied at approximately 14-day intervals. Each determination was started at about 11:00 a.m. and continued for a period of 4 hours. Adjustments were made so that approximately 60 liters of fresh air were passing over each leaf per hour.

Two sets of leaves were employed. One set was sprayed with calcium arsenate, 3 pounds; zinc sulphate, 1 pound; calcium hydrate, 2 pounds per 100 gallons. The second set was sprayed with calcium arsenate, 3 pounds, and ½ gallon of mineral oil per 100 gallons.

RESULTS

Data were obtained from determinations made in the greenhouse during the spring and summer of 1934 as to the effect of calcium arsenate with zinc sulphate and calcium hydrate buffers, and also of calcium arsenate with ½ per cent mineral oil, upon the carbon dioxide intake of sprayed Jonathan leaves as compared to that of unsprayed leaves.

Calcium arsenate with "safeners:"—Marshall and Groves (2) reported that calcium arsenate 3 pounds, zinc sulphate 1 pound, and calcium hydrate 2 pounds, per 100 gallons appeared to be an effective spray for codling moth control. The calcium hydrate and zinc sul-

[1]Published as Scientific Paper No. 304, College of Agriculture and Experiment Station, State College of Washington.

TABLE I—THE EFFECT OF COMBINATION SPRAYS OF CALCIUM ARSENATE (3 POUNDS), ZINC SULPHATE (1 POUND), CALCIUM HYDRATE (2 POUNDS) PER 100 GALLONS ON CARBON DIOXIDE INTAKE BY JONATHAN APPLE LEAVES. (EXPRESSED IN MILLIGRAMS CO_2/HOUR/100 cm^2 OF LEAF SURFACE)

Leaf No.	Average Area (Sq. cm)	Average Pedigree (5 Det.)	First Spray				Second Spray				Third Spray			
			Det. 1 Bright; occas. Cloudy	Det. 2 Bright; Clear	Det. 3 Bright; occas. Cloudy	Aver. Det.	Det. 1 Bright and Clear	Det. 2 Bright and Clear	Det. 3 Bright; occas. Cloudy	Aver. Det.	Det. 1 Bright	Det. 2 Bright and Clear	Det. 3 Bright	Aver. Det.
(a) Leaves Not Sprayed														
1	20.8	13.6	15.4	14.4	11.4	13.7	13.2	12.4	14.7	13.4	12.0	14.9	11.1	12.7
2	15.0	14.3	9.9	12.3	13.1	11.8	10.9	12.5	10.3	11.2	13.6	15.7	14.6	14.6
3	34.4	12.2	7.7	12.2	11.9	10.6	9.2	10.0	12.6	10.6	10.8	11.0	12.9	11.6
4	14.1	12.8	12.4	13.0	13.3	12.9	10.8	12.6	14.9	12.8	11.6	10.7	12.1	11.5
5	21.5	15.2	15.2	14.5	12.8	14.1	12.6	—	—	—	—	—	—	—
Average for unsprayed leaves						12.6				12.0				12.6
(b) Leaves Sprayed														
6	18.0	14.7	16.4	15.3	12.4	14.7	13.3	13.6	16.6	14.5	15.1	17.4	15.1	14.5
7	25.7	13.8	11.9	12.4	11.7	12.0	12.0	13.1	13.4	12.8	14.9	13.0	10.3	12.7
8	19.1	14.0	13.4	15.8	13.7	15.0	13.4	13.4	14.7	13.8	13.9	14.5	15.2	14.5
9	16.1	19.1	18.2	17.8	18.1	18.0	21.3	21.8	21.7	21.6	19.5	16.2	18.2	18.0
10	21.4	14.3	15.5	15.9	14.3	15.3	16.0	16.8	15.8	16.2	12.6	14.2	10.7	12.5
Average for sprayed leaves						15.0				15.8				14.4

TABLE II—THE EFFECT OF COMBINATION SPRAYS OF CALCIUM ARSENATE (3 POUNDS) ½ PER CENT MINERAL OIL (NO. 6 SUMMER OIL, EMULSIFIED WITH CASEIN-AMMONIA) PER 100 GALLONS ON CARBON DIOXIDE INTAKE BY JONATHAN APPLE LEAVES. (EXPRESSED IN MILLIGRAMS CO_2/HOUR/100 cm^2 OF LEAF SURFACE)

Leaf No.	Average Area (Sq. cm)	Average Pedigree (5 Det.)	First Spray				Second Spray				Third Spray			
			Det. 1 (Light Int., Foot Candles) 10,100	Det. 2 10,500	Det. 3 10,200	Aver.	Det. 1 (Light Int., Foot Candles) 9,000	Det. 2 9,500	Det. 3 9,750	Aver.	Det. 1 (Light Int., Foot Candles) 10,750	Det. 2 11,000	Det. 3 8,000	Aver.
(a) Leaves Not Sprayed														
1–7	29.9	14.7	14.2	13.0	11.8	13.0	12.1	12.8	11.9	12.3	12.3	11.6	10.9	11.6
2–8	26.7	12.3	13.1	12.8	12.4	12.7	13.4	12.2	13.8	13.1	11.8	12.1	11.0	11.6
3–11	24.4	14.2	14.0	13.7	13.5	13.7	14.7	12.9	13.7	13.7	12.2	11.7	11.2	11.7
4	25.1	12.0	12.7	12.9	11.7	12.4	12.8	11.9	11.6	12.1	11.7	11.9	10.8	11.5
Average for unsprayed leaves						13.0				12.8				11.6
(b) Leaves Sprayed														
5–1	24.2	12.6	10.0	15.7	11.8	12.5	11.4	11.9	12.1	11.5	10.9	11.1	10.7	10.9
6–2	26.4	13.2	11.2	12.7	12.3	12.0	12.1	11.8	12.4	12.1	11.4	11.2	11.3	11.3
7–3	23.1	11.5	12.3	14.4	13.8	13.5	13.1	13.9	11.9	12.9	12.4	12.8	11.9	12.4
8–5	19.3	13.5	14.5	13.3	12.1	13.3	13.8	12.6	12.0	12.5	13.0	12.7	12.0	12.6
9–9	19.1	12.9	12.6	11.9	12.5	12.3	11.2	12.0	11.7	11.6	10.8	11.7	12.1	11.5
10–12	22.9	12.7	13.4	12.5	12.4	12.7	12.9	13.1	12.4	12.8	12.0	12.9	12.0	12.3
Average for sprayed leaves						12.7				12.2				11.8

phate were of value in preventing arsenical injury. Under like conditions this gave 17.2 micrograms As_2O_3 per square centimeter of Jonathan apple leaf as contrasted with 24.4 micrograms for lead arsenate 3 pounds per 100 gallons. The spray of calcium arsenate with the "safeners" produced apple foliage far superior to any other spray in the experimental orchard, and weather conditions were such that lead arsenate caused considerable foliage and some fruit injury on Jonathans. The fruit from the former trees was of better color and size than from trees receiving lead arsenate, indicating greater photosynthetic capacity of leaves receiving calcium arsenate with the "safeners."

Representative data as to the effect of sprays of the calcium arsenate, zinc sulphate, calcium hydrate, upon the carbon dioxide intake of Jonathan apple leaves are in Table I.

The data in Table I indicate that Jonathan apple leaves sprayed with the calcium arsenate and safeners three successive times at 14-day intervals were not adversely affected as measured by carbon dioxide intake. In fact, the carbon dioxide intake of the sprayed leaves seemed to be slightly greater than that of the unsprayed leaves. The difference did not appear to be due to carbon dioxide absorption by the applied sprays, since sprayed "cardboard leaves" were comparable to air checks.

Calcium arsenate with mineral oil:—While lead arsenate and mineral oil has been used for some time, its use has tended to result in foliage injury greater than with lead arsenate without mineral oil, either directly from the oil or indirectly from arsenic (3). Marshall and Groves (2), however, found that calcium arsenate, 3 pounds, with ½ per cent mineral oil (emulsified at the tank with casein-ammonia), gave better codling moth control and resulted in no greater foliage or fruit injury to Jonathan apples than did lead arsenate alone.

Representative data as to the effect of sprays of the calcium arsenate (3 pounds) and mineral oil (½ per cent) per 100 gallons upon the carbon dioxide intake of Jonathan apple leaves are in Table II.

The data in Table II do not indicate that the three successive sprays of calcium arsenate and mineral oil as applied to 1-year-old Jonathan apple trees in the greenhouse adversely affected the carbon dioxide intake of the leaves.

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The Effects of Certain Fertilizers upon the Carbon Dioxide Intake of Mature Jonathan Apple Leaves[1]

By L. E. Tompkins, *State College of Washington, Pullman, Wash.*

COMMERCIAL fertilizers applied to the soil have been suggested as possibly influencing the photosynthetic capacity of apple leaves (3). Hence, during the late summer of 1934 studies were made of the carbon dioxide intake of the Jonathan apple leaves in the Von Osten fertilizer plots (3). The fertilizers used in this problem were nitrogen, phosphoric acid, and potash. There were five plots, namely, N, P, NP, NPK, and Check.

Method and Materials

The apparatus used for measurement of the carbon dioxide intake by apple leaves was similar to that used by Heinicke and Hoffman (1, 2). Sixteen determinations could be made simultaneously and the equipment could be transferred from one field plot to another. The assimilating chambers were of the cellophane envelope type (2).

By using approximately 20 feet of ¾-inch pipe for each air intake tube, it was possible to reach two plots with a buffer tree between them with each set-up. This effected a saving in the amount of rubber tubing necessary and lessened the resistance to air passage due to the larger bore of the pipe. The suction was supplied by an electric-driven pump. A temporary electric line was run to the different points in the orchard. By using a by-pass arrangement, the "dead" air in the tubes was removed and replaced by air that had passed over the leaves before the determinations were started.

The Jonathan trees used were those in a fertilizer experiment continued since 1927. The trees are 25 years old, set 25 feet apart on the diagonal in a fine sandy loam type (4) of soil of the Ephrata series in the East Wenatchee district. Each tree had been fertilized annually with 1 pound of actual nitrogen (N) in the form of sulphate of ammonia (5 pounds), 1 pound of actual phosphoric acid (P) in the form of superphosphate (6 pounds), and 2.5 pounds of potash (K) in the form of muriate of potash (5 pounds).

The trees at the start of the fertilizer experiment were uniform but at the present time the nitrogen fertilized trees are somewhat the larger. The trees receiving the P alone have made the least growth. The check trees are smaller than the nitrogen fertilized trees but are making more growth than the phosphorus fertilized trees.

Six shoot leaves from one tree in each plot were used. These leaves were healthy and of an average size and color for all the plots with the exception that the leaves on the non-nitrated trees did not have as deep a green color as did those of the nitrogen plots. In order to make the leaves from all plots as nearly the same size as feasible, the

[1]Published as Scientific Paper No. 305, College of Agriculture and Experiment Station, State College of Washington.

selected leaves from the nitrogen plots were somewhat smaller than the average for those plots and the selected leaves from the P plot were slightly larger than the average for that plot. The selected leaves were upon the south side of the tree where they were exposed to the sun. The trees were representative of the plots except in the case of the check tree which did not produce as large a crop this year as did the other check trees. The crop was harvested the week previous to the start of the determinations on September 4. The trees were irrigated to the extent that the surface soil was moist throughout the determinations.

Two plots were employed for each determination using the air checks near the six experimental leaves on each tree to determine the amount of carbon dioxide in the surrounding air. The dates of determinations were made upon the trees of the various plots as follows:

Sept. 4—NP and P
Sept. 5—NP and P
Sept. 6—NPK
Sept. 7—NPK
Sept. 8—Check
Sept. 10—Check
Sept. 11—N
Sept. 12—N
Sept. 13—N
Sept. 14—NP and P
Sept. 15—NP and P
Sept. 16—NPK
Sept. 17—NPK
Sept. 18—N
Sept. 19—N
Sept. 20—Check
Sept. 21—Check

Night determinations were made of each plot on the following dates:

Sept. 11—N
Sept. 14—NP and P
Sept. 17—NPK
Sept. 20—Check

The determinations were started at approximately the same time, usually 9 a.m. for the day determinations and 9 p.m. for the night determinations. The duration of each set of determinations was 5 hours in all cases.

A record of the temperature, humidity, light intensity, and wind velocity was taken for each determination. Fig. 1 shows the small variation in weather conditions, except September 11, 12, and 13, which were cloudy and cool with a high relative humidity due to the rain during the determination on September 12.

Results

The results are expressed in terms of milligrams of carbon dioxide absorbed per 100 square centimeters of leaf surface per hour. The carbon dioxide absorptions in September were not as high as earlier in the season, but in no case did they show a marked decrease during the 19 days when the determinations were made.

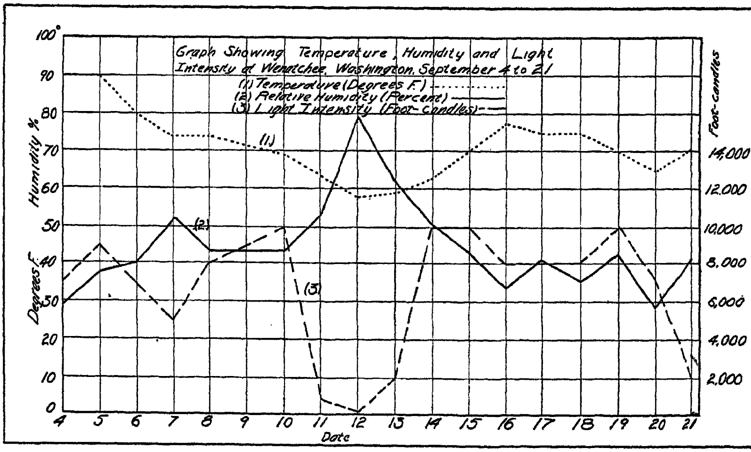

FIG. 1. Temperature, humidity, and light intensity at Wenatchee, Washington.

Representative determinations upon leaves on the trees of the fertilizer plots are in Table I.

TABLE I—MILLIGRAMS CO_2 ABSORBED PER 100 CM^2 PER HOUR BY LEAVES IN THE NP, P, NPK, N, AND CHECK PLOTS

Treatment	Sept. 4	Sept. 5	Sept. 14	Sept. 15		Average
NP.....	4.591	8.156	9.404	8.099		7.563
P.......	2.230	5.656	4.081	2.854		3.730
	Sept. 6	Sept. 7	Sept. 16	Sept. 17		Average
NPK....	9.745	4.496	6.597	3.702		6.135
	Sept. 11	Sept. 12	Sept. 13	Sept. 18	Sept. 19	Average
N.......	6.989	11.883	4.635	7.162	3.723	7.667
	Sept. 8	Sept. 10	Sept. 20	Sept. 21		Average
Check...	9.392	4.027	6.346	5.548		6.328

From the results in Table I the leaves of the nitrogen plots and of the NP plots were comparable with regard to the carbon dioxide intake while the leaves of phosphorus plats were much lower in their carbon dioxide absorption capacity. The carbon dioxide intake by the leaves of the trees in the complete fertilizer plots (NPK) averaged somewhat less than the intake by the leaves of the N or NP plots and was comparable to the intake by the leaves of the check trees.

According to Larson's (4) leaf analyses, when P alone was applied the per cent of P in the leaf was much higher than when the fertilizers

included in addition N or K either alone or together with P. This makes it appear that the P may have a depressing effect when it is applied alone or when a large amount of P is shown by the leaf. Larson made his analyses on the same plots in 1931.

With only one set of determinations upon the leaves of each plot made during the night no definite conclusion could be drawn but it was found that a leaf that was absorbing only a small amount of CO_2 during the day was giving off a larger amount at night. Also when a leaf was absorbing a relatively large amount during the day, there was a very small amount given off during the night following and in some cases there was even a very small intake of carbon dioxide. This latter may have resulted from the fact that the supply of carbon dioxide in the intercellular spaces of the leaves had been so completely utilized during the day that the cell contents had not yet become saturated by the carbon dioxide of respiration and thus continued to absorb carbon dioxide from the surrounding air until the partial pressure differences inside and outside of the leaf became the same or were reversed. Furthermore, the drop in temperature during the night determinations would increase the solubility of the carbon dioxide in the leaf.

Discussion

In general, the carbon dioxide intake capacity of Jonathan apple leaves seemed correlated with the tree response as measured by annual terminal growth, tree trunk circumference increase, and weight of harvested fruit per tree (Overley and Overholser, 1934, unpublished), i. e., the more marked the tree response to fertilizers the greater the carbon dioxide intake and the less the tree response the less the carbon dioxide intake by a given leaf area. This is in addition to the apparent correlation (3) that the greater the growth and fruiting response, the greater the average leaf area per tree and vice versa. In other words, the influence of fertilizers may be through affecting not only the total leaf area but also the functioning of a given leaf area. Insofar as tree growth and fruiting response may be measured, however, the fertilizer influence upon either total leaf area or functioning per given leaf area may be masked by the other.

Acknowledgment

The writer wishes to thank Doctor E. L. Overholser under whose directions this study was made; also Professor F. L. Overley who made it possible to use the fertilizer experimental plots in Wenatchee.

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Fish Oil Sprays as Affecting the Carbon Dioxide Intake by Jonathan Apple Leaves[1]

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WITH the commercial production of apples, there is a general use of oil sprays during the season when the leaves are most active in the process of manufacturing food materials. Hoffman (4), Dutton (1), Hedrick (2), and others have reported upon the effect of various spray materials upon the carbon dioxide intake by apple leaves, even when no visible injury to the leaf tissue was noticed. This paper reports studies of carbon dioxide intake by Jonathan apple leaves following several successive herring oil-lead arsenate[2] sprays applied during the spring of 1933.

Methods and Materials

The apparatus for the measurement of the carbon dioxide intake by the leaves was that described by Heinicke and Hoffman (3) with certain modifications. The absorption chamber used was of the cellophane envelope type fitting over the leaf and fastened at the petiole and suction tube by means of paper clips. The cellophane chambers were placed over sprayed and non-sprayed leaves, and also over the air check intakes. The apparatus had 12 absorption towers, five of which were used for sprayed leaves, five for non-sprayed leaves, and two for determining the amount of carbon dioxide in the atmosphere.

Jonathan trees, 1-year-old, growing in good loam soil in 14-inch pots in the greenhouse, under controlled temperature and humidity conditions, were used in this experiment. Leaves were selected for their uniformity of age, color, size, and vigor. Only leaves on shoot growth were used. Sprays were applied with a power-driven atomizer type of sprayer, 16 hours before the first determination following each spray. Successive determinations were made at 2-day intervals. Each determination was started at 8:00 a. m. and ran for a period of 4 hours. Adjustments were made so that 50 to 55 liters of fresh air were passing over each leaf per hour. With this amount of air on days with very good sunshine in the late spring, there was some condensation of moisture on the inside of the envelope, but with the greenhouse conditions, this was not serious.

Herring fish oil was used at the rate of 1 quart combined with 3 pounds of arsenate of lead to 100 gallons of spray. The leaves were thoroughly sprayed on both sides, with the adjacent leaves being protected from the spray with water-proofed paper.

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[2]The herring oil used met the requirements of remaining a liquid at 65 degrees F, being slow drying with an iodine number between 120 and 145, and containing approximately 1 per cent organic acid (as oleic). A commercial brand of arsenate of lead was used.

TABLE I—EFFECT OF HERRING OIL AND LEAD ARSENATE COMBINATION SPRAY UPON THE CO_2 INTAKE BY JONATHAN APPLE LEAVES
(Expressed in Milligrams CO_2/hour/100 cm^2 of Leaf Surface)

Trial Run		First Spray			Second Spray				Third Spray		
		Run 1	Run 2	Ave.	Run 1	Run 2	Run 3	Ave.	Run 1	Run 2	Ave.
(a) Leaves not Sprayed											
1	19.9	14.5	14.2	14.3	13.0	14.5	13.8	13.7	16.6	14.6	15.6
2	12.4	—	—	—	16.2	14.6	15.7	15.5	17.7	16.8	17.2
3	18.3	13.7	16.9	15.3	22.1	14.5	15.3	17.3	17.7	15.1	16.4
4	15.6	10.1	12.0	11.1	14.5	8.8	16.3	13.2	12.8	11.5	12.2
5	17.1	12.3	14.6	13.4	19.0	10.4	16.6	15.3	12.6	10.8	11.7
Average all non-sprayed leaves	16.7			13.5				15.0			14.6
(b) Leaves Sprayed											
6	17.3	13.4	14.5	14.0	10.2	13.1	11.6	11.6	6.5	10.6	8.5
7	20.3	16.0	14.7	15.3	13.1	11.1	—	12.6	8.9	13.3	11.1
8	15.6	12.0	12.3	12.1	12.5	7.4	12.4	10.8	8.4	7.7	8.0
9	10.9	9.7	15.3	12.5	14.4	13.2	15.2	14.3	7.6	9.5	8.5
10	11.0	10.0	13.7	11.9	9.3	9.4	10.4	9.7	7.1	5.7	6.4
Average all sprayed leaves	15.0			13.2				11.8			8.5
Light:—	Good sun	Good sun	Good sun		Partly cloudy	Good sun	Cloudy		Good sun	Good sun	
Temp. (Degrees F):—	73	72	73		73	71	72		74	74	

RESULTS

Representative results obtained from this series of determinations, as to the effect of herring oil-lead arsenate combination sprays upon the carbon dioxide intake by the leaves are presented in Table I.

Data in Table I indicate that non-sprayed leaves vary in their ability to absorb carbon dioxide from the atmosphere. Environmental conditions such as amount of carbon dioxide in the atmosphere, light intensity, temperature, relative humidity, and soil moisture, all greatly influence the amount of carbon dioxide taken in by the leaf. Carbon dioxide content of the atmosphere varied from .47 to .52 milligrams per liter of air. Following the first spray application, there was apparently a recovery from the effect of the spray, as shown by the results of the second determination. Determinations made following the second and third spray applications did not, however, seem to indicate similar recovery. There was a definite decrease in the amount of carbon dioxide taken by the leaves following each succeeding spray application. These results are from one series of determinations, and can not be taken as conclusive, but do indicate that herring oil-lead arsenate spray combination on apple foliage may have a detrimental effect upon the leaves by way of lowering their capacity to remove carbon dioxide from the air. There was no visible injury to any of the leaves caused by the three oil spray applications. These findings are in agreement with those observed under field conditions by Webster, Marshall, Overholser and Overley (5). Injury was observed, under field conditions, when a poor grade of herring oil was used in the oil-lead arsenate spray combination and when four, five or more sprays were applied (5).

A considerable reduction in the carbon dioxide intake by apple leaves can be excepted when three, four or more herring oil-lead arsenate combination sprays are thoroughly applied to their surfaces.

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The Effects of Several Summer Oils on the Carbon Dioxide Assimilation by Apple Leaves

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SEVERAL investigators (3, 4, 5, and 6) have shown that oils of low refinement and relatively high viscosity are not suitable for summer spraying since they are toxic to foliage. Numerous commercial brands of emulsified oils for summer spraying are now being offered for sale. It could hardly be expected that standardization has reached a degree where all of these oils possess the chemical and physical characters which make for the minimum amount of visible foliage injury. There is always the possibility that some of them may interfere with normal leaf metabolism even tho there is no visible injury.

The effects of three commercial brands of summer oils on the carbon dioxide assimilated by apple leaves were studied during the past summer. The method used in determining the rate of CO_2 assimilation has been described (1, 2). The foliage of vigorous 7-year-old Northern Spy apple trees growing in an alfalfa sod provided experimental material. The same procedure used in studies on the effect of lime sulphur on the photosynthesis of apple foliage was employed in this work (2). Briefly it was as follows: the rate of CO_2 assimilation for individual leaves was determined for several days before any treatment was given. This is necessary because normal leaves vary appreciably in their activity even though environmental conditions are the same. When the relationship of the separate leaves to one another was thus established some of the leaves were sprayed with summer oil emulsion and the remainder were left as checks. The assimilation rates of these leaves were then studied for several days. All determinations were made in the forenoon and lasted for 5 hours. Each brand of the oil emulsion was diluted so that the spray mixture contained exactly one per cent of oil by volume. A small atomizer was used in making the application and the leaves were sprayed on both surfaces.

Table I gives the results obtained in a series of determinations and shows how the different oils effected the amount of CO_2 removed from the air by the leaves. In the left hand column of this table the leaf numbers are arbitrary numbers assigned to leaves at the start of the experiment for the convenience of orderly records. The data in the second column give the milligrams of CO_2 assimilated per hour per 100 square centimeters of leaf surface for the separate leaves during the morning of August 17. With respect to the rate of photosynthesis this would not be regarded as a very uniform set of leaves; however, during four similar determinations preceding the one reported for August 17 these leaves maintained approximately the same relationship to each other.

At 6 p. m. on August 19, leaves 1 and 2 were sprayed with summer oil A, leaves 4 and 5 with summer oil B, leaves 7 and 8 with summer oil C, and leaves 3 and 6 were left untreated for checks. The assimilation rates of these leaves were determined each day for 5 days following the spray treatments. The remaining columns in the table give

TABLE I—THE EFFECT OF SEVERAL SUMMER OILS ON CO_2 ASSIMILATION BY APPLE LEAVES

Leaf No.	CO_2 Assimilated (MgHr 100 Cm^2)	Treatment	CO_2 Mg Hr 100 Cm^2 Expressed in Per cent of Assimilation Before Treatment				
	Aug. 17, 1934	6 p.m. August 19	Aug. 20	Aug. 21	Aug. 22	Aug. 23	Aug. 24
1	17.7	Sum. oil A	–4.5	16.9	–1.1	–3.3	–1.6
2	15.9	Sum. oil A	11.3	16.9	1.8	–10.6	14.4
3	21.9	Untreated	82.6	89.0	54.7	92.6	84.9
4	15.2	Sum. oil B	15.1	20.3	7.2	29.6	42.7
5	16.4	Sum. oil B	14.0	34.1	3.6	3.6	25.6
6	11.5	Untreated	99.1	88.6	69.5	116.5	86.0
7	13.3	Sum. oil C	—	75.9	56.3	98.4	85.7
8	17.3	Sum. oil C	86.1	87.2	53.1	101.7	85.5
			Temperature (Degrees C)				
Max.	25	—	20.5	22.5	23.8	21.0	26.5
Min.	18	—	19.0	18.0	15.0	17.5	19.5
			Weather				
	Cloudy Intermittent sun	—	Intermittent sun	Clear	Hazy—rain	Hazy	Cloudy, intermittent sun

the results of these determinations. The results after spraying are expressed as percentages of the "normal" rate as determined prior to treatment.

These data show that the application of oil A materially reduced the amount of CO_2 that leaves 1 and 2 were capable of removing from the atmosphere. In the case of leaf 1 respiration exceeded photosynthesis during every determination after treatment with the exception of the one on August 21. This is shown by the minus quantities recorded for this leaf on August 20, 22, 23, and 24, which means that CO_2 was given off to the atmosphere in greater quantities than it was absorbed. Although leaf 2 showed a minus quantity for an assimilation rate on only 1 day of the 5 following treatment, the highest rate of assimilation revealed for this leaf was only 16.9 per cent of its rate before spraying. This occurred on August 21, the same day that leaf 1 showed an assimilation in excess of respiration.

When the results of the determinations on leaves 4 and 5 following treatment are compared with those of the untreated leaves, it is obvious that the application of oil B reduced the amount of CO_2 removed from the atmosphere by these leaves. Photosynthesis exceeded respiration during all the determinations for leaves 4 and 5 and in general the assimilation rates were appreciably higher than those recorded for leaves 1 and 2 on any given day. The injurious effects of oil B were quite severe but not as severe as oil A.

The results of determinations on the untreated leaves indicate that August 17 was a better day for photosynthesis than any of the 5 days following the spray application. The only exception to this is the results on leaf 6 for August 23. In considering the effects of oil C on leaves 7 and 8 one observes that the comparative rates of assimilation of these leaves after treatment is slightly greater in most cases than they were for the untreated leaf 3 but not quite as great as they were for the untreated leaf 6. Apparently oil C did not significantly reduce the rate of assimilation of leaves 7 and 8. Other experiments with this oil support this conclusion.

None of the three oils used in this work caused any visible destruction of leaf tissue.

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Some Factors Affecting Fruit Set in Pears[1, 2]

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PEAR production in the Rogue River Valley is often relatively low because the fruit set is insufficient to give fully loaded trees. This is particularly true for the Anjou. To determine the relative value of pollination, fruit thinning, nitrogen fertilization and pruning in increasing fruit set, a series of experiments was started in 1932.

POLLINATION

The pollination tests were designed to measure the effectiveness of cross pollination for Anjou and Bartlett. Entire limbs of representative trees were covered with cheesecloth or muslin bags before the petals had opened. For "selfed" pollination, the bags were left on until after petal fall and the blossoms left without hand pollination. For "open" pollination, fruit set on adjacent, untouched limbs was measured. For "hand crossed" pollination, the bags were removed temporarily during early full bloom, and the pistils of each blossom dusted with pollen. With Anjou at least 10 limbs were used for each treatment, but with Bartlett only two or three limbs were used. The percentage of fruit set was based on the total number of individual blossoms. The decrease in per cent of fruit set, expressed as percentage of initial fruit set, is termed "drop of small fruits". The results are give in Table I.

TABLE I—EFFECT OF TYPE OF POLLINATION UPON FRUIT SET AND DROP OF SMALL FRUITS

	Type of Pollination	Number Blossoms Used	Blossoms Setting Fruit (Per cent)		Drop of Small Fruits (Per cent)
			May 8	June 16	
Anjou 1933	Selfed..................	1,759	10.7	2.9	73
	Open....................	1,571	12.8	6.0	53
	Hand crossed by Bartlett	1,358	25.3	5.5	78
			April 13	*June 14*	
Anjou 1934	Selfed.................	2,328	.3	.3	0
	Open...................	1,120	3.0	2.0	70
	Hand crossed by Bartlett	2,840	32.1	3.2	90
Bartlett 1934	Selfed.................	1,128	16.3	7.4	55
	Open...................	952	13.2	6.3	52
	Hand crossed by Anjou...	960	41.4	9.2	78

With Anjou in both 1933 and 1934 open pollination gave a higher initial fruit set than self pollination, but hand cross pollination gave the greatest initial fruit set. For Bartlett, hand cross pollination gave

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the best initial fruit set, but "selfed" was slightly better than "open".

However, the final fruit set (after the fruit drop) determines the amount of crop. In 1933 the drop of Anjou fruits following hand cross pollination was so much greater than that following open pollination that the final fruit set or crop with the hand cross pollination was slightly lower than with open pollination. In 1934 the drop of Anjou fruits following hand cross pollination was again greater than the drop following open pollination, but the initial fruit set from hand cross pollination was enough greater than that from open pollination to give a greater final fruit set. Likewise, although the Bartlett fruit drop was greatest on the hand cross pollinated limbs, this fruit drop was not sufficiently great to prevent the final fruit set following hand cross pollination from being greater than that for selfed or open pollination.

This greater fruit drop following the more thorough hand cross pollination than following the open pollination seems very important, for it shows that without proper nutrition of the small fruits to prevent their dropping, increased cross pollination may not of itself increase the final crop.

Fruit Thinning in the Previous Season

In 1932 fruit thinning of Anjou was tried, in an effort to reduce the total amount of plant food utilized by the growing fruits and, by increasing food storage or otherwise stimulating tree vigor, to improve the nutrition of the small fruits the following spring. Therefore, on May 13 (36 days after the beginning of full bloom, when there were about 20 leaves per fruit) groups of three trees were thinned to 30, 50, and 70 leaves per fruit, respectively. On May 24 these three treatments were repeated on additional trees. On June 14, after the June drop (of small fruits), when average trees had about 40 leaves per fruit, groups of six trees were thinned to 60 and to 100 leaves per fruit. On June 28, other six-tree groups were thinned to 100 leaves per fruit. The following spring (1933) fruit set for these thinned trees and for comparable unthinned trees was determined by counting, on six limbs per tree, blossom clusters, fruits about 30 days after full bloom, and fruits again after the June drop. Blossom cluster counts were multiplied by 8 to give the number of individual blossoms.

It was found that trees thinned on May 13, 1932, to 30, 50, or 70 leaves per fruit, showed after the June drop in 1933, $1.6\pm.33$, $1.6\pm.41$ and $1.2\pm.32$ increases, respectively, in per cent fruit set, as compared with unthinned trees. Statistically, this fruit thinning the previous spring resulted in very small increases in fruit set. However, trees thinned on May 24, on June 14, or on June 28 in 1932 showed no suggestion of increased fruit set in 1933, as a result of thinning.

Anjou fruit thinning of the same type was repeated in 1933, using particularly uniform trees in irrigation Plots E and F. Before thinning the leaf-fruit ratio for these trees was determined, as previously described for thinning experiments in Plot E (2). All limbs of the check trees were adjusted by fruit removal to 50 leaves per fruit,

the minimum on any limb. Thinned trees were adjusted by fruit removal on July 7 or 8, 1933, to 75 leaves per fruit. The fruit set in 1934 is given in Table II.

TABLE II—EFFECT OF FRUIT THINNING IN 1933 UPON FRUIT SET IN 1934

Variety and Vigor	Date of Thinning in 1933	Treatment in 1933	Growing Points Blossoming in 1934 (Per cent)	Blossoms Setting Fruit in 1934 (Per cent)		Crop, or Bloom x Set
				Initial	Final	
Anjou Plot E Vigorous	July 8	Check 50 l.p.f. Thinned 75 l.p.f.	— —	5.3± .24 6.0± .34	2.0±.14 2.6±.20	— —
Anjou, Plot F Mod. Vigor	July 7	Check 50 l.p.f. Thinned 75 l.p.f.	— —	4.8± .40 5.6± .42	1.3±.07 2.3±.17	— —
Bartlett Vigorous	June 15	Check 25 l.p.f. Thinned 30 l.p.f. Thinned 40 l.p.f. Thinned 50 l.p.f.	23 37 34 44	— — — —	5.6±.52 5.1±.97 6.4±.38 5.3±.38	.0129 .0189 .0218 .0233
Comice Low Vigor	June 4	Check 30 l.p.f. Thinned 100 l.p.f.	15 41	32.4±1.32 35.1±2.27	3.2±.29 6.4±.39	.004 .026

After the June drop in 1934, the average fruit set of thinned Anjou trees in Plot E differed from the check trees by 0.6±.24 per cent set. Thinned Anjou trees in Plot F differed from their corresponding check trees by 1.0±.18 per cent set. Thus, only for the moderately vigorous Anjou trees in Plot F did the fruit thinning in 1933 significantly increase fruit set in 1934. Although numerically the difference is very small, it represents a 77 per cent increase over the unthinned trees.

The fruit set of Bartlett, following the previously described (2) thinning treatments in 1933, is given in Table II. The final fruit set of these Bartlett trees was not increased by fruit thinning in 1933. However, the amount of bloom was increased by that thinning, and from the figures for "crop" (bloom x set) it is evident that fruit thinning in 1933 increased the 1934 crop; or in other words, fruit set in proportion to the amount of bloom was increased by the thinning.

Three very devitalized Comice trees were thinned on June 4, 1933, to approximately 100 (very small) leaves per fruit. As compared with unthinned (check) trees, this thinning of Comice in 1933 not only increased the amount of blossoms, but also increased the per cent of the blossoms setting fruit.

These results show that fruit thinning of pears may result in increased fruit set the following year, thus agreeing with the somewhat similar results indicated by Waring (9) for plums, and by Aldrich (1) and Palmer (6) for apples. More extensive experiments are necessary to determine whether the increased fruit set, following thinning the previous season, would justify the expense and reduced crop in the year of thinning.

Nitrogen Fertilization

Since a late fall or early spring application of nitrogen fertilizer has elsewhere frequently been found to increase fruit set, the value of such fertilizer for the Anjou trees just discussed was determined in a preliminary way. The treatments and results are given in Table III.

TABLE III—Effect of Nitrogen Fertilizer upon Fruit Set

Plot	Fertilizer Treatment	No. Trees Used	Fruit Set After June Drop (Per cent)	
			1933	1934
A	2½ lbs. Am. Sul. per tree fall 1931 7½ lbs. Am. Sul. per tree fall 1932 5 lbs. Am. Sul. per tree fall 1933	2	3.8±.42	2.4±.29
B	2½ lbs. Am. Sul. per tree fall 1931 No fertilizer in 1932, 1933, or 1934	3	3.9±.17	1.9±.21
C	2½ lbs. Am. Sul. per tree fall 1931 15 lbs. Sod. Nit. per tree spring 1933 No fertilizer in fall 1933 or in spring 1934	2	3.9±.17	2.7±.27

The data in Table III show no lack of fruit set in Plot B in 1933, due to lack of nitrogen fertilization in the fall of 1932, and no statistically significant difference between plots in 1934. However, casual observation in 1934 showed an appreciably lighter crop and a lighter green color of foliage in Plot B, without nitrogen fertilization since the fall of 1931, than in Plots A and C. The 26 per cent and 42 per cent greater fruit sets in Plots A and C, respectively, than in Plot B, would probably have been statistically significant if more than two trees had been used. The same fruit set in Plot B as in Plot A in 1933 indicates that a residue of nitrogen in the soil or in the tree from the 1931 fall application of ammonium sulphate supplied the nitrogen needs of the blossoms and small fruits in Plot B, the second season after nitrogen fertilization, fully as well as did nitrogen applied to Plot A the previous (1932) fall. A comparison of Plots C and A in 1934 suggests the same hold-over of residue, or reserve, nitrogen.

The results suggest that, for Meyer clay adobe soil with a rye-vetch cover crop, without the application of a nitrogen fertilizer, soil nitrogen may become sufficiently low at the end of two years to limit fruit set. Reimer (9), also working in the Rogue River Valley, apparently increased fruit set of Winter Nelis on Medford gravelly clay loam by applying nitrogen fertilizer. In Lake County, California, Proebsting (8), using Bartlett pears, found that nitrogen carrying fertilizers increased fruit set.

Pruning

Observations, showing that for Anjou trees low in vigor some pruning was necessary to obtain any appreciable fruit set, led to rather extensive studies of the influence of pruning upon fruit set.

Results in 1933:—The Anjou trees available in February 1933 had received a heavy thinning-out and heading-back the previous

TABLE IV—EFFECT OF PRUNING IN FEBRUARY, 1933, UPON FRUIT SET AND DROP OF SMALL FRUITS DURING SPRING OF 1933

Type of Pruning	No. Trees	Fruit Buds Removed in Pruning (Per cent)	Shoot Length Removed in Pruning (Per cent)	Bloom After Pruning (Per cent of Total Growing Points)	Blossoms Setting Fruit (Per cent)		Total Crop (Per cent Bloom x Per cent Set)		Drop of Small Fruits (Per cent)
					May 8–20	June 20–26	May 8–20	June 20–26	
Light pruning	3	5	61	41	10.5± .54	3.3±.14	4.34	1.44	67
Shoot removal	4	5	87	42	15.2± .53	4.4±.13	6.78	1.84	71
Heavy pruning	3	25	87	34	23.3± .84	5.8±.40	7.95	1.97	75
Dehorning	4	—	—	40	46.9±1.51	5.7±.25	18.79	2.28	88
Defloration	4	88	61	27 (7)*	42.6	27.9	2.98	1.95	35
Light pruning	6	5	60	38	11.7± .56	4.2±.13	4.60	1.56	66
Spur pruning	4	36	60	26	24.8± .87	7.1±.23	6.44	1.85	71

*In deflorating, half of blossoming points (originally 54 per cent bloom) were entirely removed; and of the remaining half, six of the eight flowers per cluster were removed.

TABLE V—EFFECT OF PRUNING IN JANUARY, 1934, UPON FRUIT SET DURING SPRING OF 1934

Variety	Anjou		Bartlett		Bosc		Winter Nelis		Comice	
Date of Set	April 4	June 22	April 6	June 22	April 21	July 18	April 21	July 18	April 9	June 22
No pruning	10.3±1.01	1.5±.13	30.9±1.53	6.5±.41	37.4±2.40	10.3±.56	5.0±.42	4.0±.33	27.5±1.44	2.8±.22
Spur removal	15.5± .68	2.5±.24	32.5±1.95	6.5±.47	25.5±1.31	8.3±.58	5.4±.44	4.7±.27	42.6±2.00	5.7±.39
Heavy pruning	22.6±1.96	3.3±.39	44.4±2.63	12.2±.94	64.5±2.04	19.2±.63	8.7±.53	6.8±.41	23.6±3.23	3.1±.50

winter. These trees were moderately vigorous at the start, and were in irrigation plots with soil moisture maintained, through the cooperation of Mr. R. A. Work of the U. S. Bureau of Agricultural Engineering, above 40 to 50 per cent of the available capacity in the 0–3 foot soil depth. Fruit set determinations were based on blossom and fruit counts of three to four entire trees per treatment. The type of pruning, with its effect upon fruit set, is given in Table IV.

The data in Table IV show that the heavier pruning, as compared with "light pruning", gave statistically significant increases in final fruit set. The poorest fruit set was obtained with "light pruning", although this treatment consisted in removing 61 per cent of the shoot length and 5 per cent of the fruit buds. In general, there seemed to be a direct correlation between severity of pruning and the amount of initial fruit set. However, in the case of "dehorning" the very high initial fruit set was followed by an unusually heavy drop of small fruits, with the result that the final fruit set was about the same as that of "heavy pruning".

Following "defloration", which removed about seven-eighths of the blossoms from the tree, fruit set in the remaining blossoms was increased several fold. This suggests that a reduction in the heavy fruit bud formation of the Anjou variety might result in a greater set of fruit for that variety.

The results, from defloration as well as from pruning, indicate that both the removal of fruit buds and the removal of wood are important factors in the increased set of fruit following the heavier pruning treatments. The removal of fruit buds by pruning apparently reduces competition among the remaining buds, possibly for both water and food materials. The increased fruit set following heavier pruning in 1933 was greater and apparently more significant than the increase in fruit set obtained from fruit thinning the previous season or from the use of a nitrogen fertilizer.

Results in 1934:—In 1934 the effect of pruning in increasing fruit set was measured for Anjou and also for four other important pear varieties in the Rogue River Valley. Four trees of each variety were given each treatment, and fruit set was measured by counting blossom clusters and fruits on six small limbs per tree. "Heavy" pruning removed approximately as many fruit buds as "Spur" pruning, and removed a great deal more wood. The results are given in Table V.

"Spur" pruning increased fruit set for moderately vigorous Anjou, but not for moderately vigorous Bartlett, Bosc or Winter Nelis. Such results may be typical for Anjou, Bartlett and Bosc. For Winter Nelis, however, it is probable that severe infections of so-called pear blast, probably *Phytomonas syringae* (Rosen), during full bloom thinned out sufficient blossoms on the unpruned trees to give a greater fruit set than would normally be expected, and thus may have prevented a lower fruit set than for "spur pruning". With seriously devitalized Comice trees "spur pruning" showed greatly increased fruit set, as compared with no pruning.

"Heavy" pruning increased fruit set for Anjou, Bartlett, Bosc, and Winter Nelis, but not for Comice. Although the heading-back

of Comice was not as severe as for the other varieties, this lack of increased fruit set following a heading-back pruning agrees with the commercial experience of many growers.

The greater fruit set, with or without pruning, for Bartlett than for Anjou, as given in Table V, is typical of the difference in fruit set between these two varieties. The large differences between initial and final fruit sets for all varieties, except Winter Nelis, is also typical in the Rogue River Valley.

This effect of pruning in increasing fruit set of pears has been found elsewhere. According to Chandler (4), fruit growers in New York reported that, with Anjou trees dropping all or nearly all of their bloom every year, severe pruning caused the trees to hold good crops. In the Hood River Valley, Brown and Childs (3) found that heavy pruning of crowded, nitrogen-deficient Anjou trees increased the yield; but they felt that with adequate soil nitrogen and exposure to sunlight, continued heavy pruning was not necessary.

MacDaniels and Heinicke (5), in discussing the factors which affect the fruit set of apples, have pointed out that pruning increases fruit set, presumably by improving the supply of water and soil nutrients to the growing tissues and by otherwise increasing the vigor of the growing points. Thus the effectiveness of pruning in improving fruit set suggests that all factors which stimulate the vigor of bearing trees may be factors which will increase pear fruit set.

Discussion

The large drop of small fruits, particularly after an initially heavy fruit set, indicates a nutritional deficiency in the tissues of small fruits or in adjacent stems and twigs. The slightly lower fruit set for hand cross pollinated than open pollinated Anjou in 1933 suggests that other conditions besides adequate cross pollination may be necessary to give those nutritional conditions required for sufficient fruit set for a large commercial crop.

Such nutritional conditions were apparently affected to a small extent by the amount of crop the previous season and by the use of nitrogen fertilizers. However, since both the wood removal and the blossom bud removal of pruning materially increased fruit set, the nutritional conditions following heavy pruning would seem to be of particular importance. Additional studies are in progress, to determine the nature of the nutritional conditions involved.

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Evaporating Power of the Air and Top-root Ratio in Relation to Rate of Pear Fruit Enlargement[1, 2]

By W. W. Aldrich, and R. A. Work, *U. S. Department of Agriculture, Medford, Ore.*

PREVIOUS studies of the responses of pear trees to soil moisture in clay adobe soil (2) showed that rate of fruit enlargement, duration of stomatal opening and wood growth were influenced by soil moisture differences within the available range. Additional results by Lewis, Work, and Aldrich (6) also showed that the rate of fruit enlargement was rather closely correlated with the amount of available soil moisture between the wilting percentage and 80 per cent of the available capacity. These studies were continued in 1933 and 1934, with essentially the same results. Some of the results in 1934, here reported, seem to show somewhat more clearly the relation between soil moisture and pear tree response.

Soil Moisture and Fruit Enlargement

With trees, soil and technique similar to that previously (2) described, fruit enlargement was measured on 20 fruits on each of three trees between 7 and 9 a. m. at semi-weekly intervals and determinations of soil moisture content were made at 5 locations at intervals of 7 to 10 days in each of two plots (E and G). In Plot E the soil moisture was maintained high in the available range by frequent irrigation, but in Plot G the soil moisture was allowed to decrease almost to the wilting percentage before replenishing by irrigation. However, at no level in any sampling location in Plot G, was the soil moisture allowed to reach the wilting percentage. Therefore, as far as it was determined, no part of the root zone lacked available water during the season of fruit growth. The available soil moisture in the upper foot and the average in the upper 3 feet of Plots E and G, together with the average rate of fruit enlargement for the periods between measurements are given in Fig. 1.

The greater rate of fruit enlargement in Plot E than in Plot G from July 7 to August 3 and from August 10 to 23 illustrates the greater rate of fruit enlargement on trees having the greater average available soil moisture. This difference began when the drier plot contained moisture up to 60 per cent of its available capacity.

Fruit enlargement rate in Plot G was more rapid than in Plot E on two occasions, both immediately following the irrigation of Plot G. This was probably due more to a rapid increase in turgor of the fruit in Plot G following the irrigation than to the temporarily greater soil moisture in Plot G than in Plot E.

However, certain maxima and minima in rate of fruit enlargement, particularly for Plot G, do not seem directly correlated with the

[1]This is a report of a cooperative project between the U. S. Department of Agriculture and the Oregon Agricultural Experiment Station.

[2]Published as Technical Paper No. 232 with the approval of the Director as a contribution of the Medford Branch of the Oregon Agricultural Experiment Station.

amount of available soil moisture. Such fluctuations in rate of fruit enlargement seem characteristic for pears in the heavy soils of the Rogue River Valley. In a fine sandy loam similar irregularity in fruit enlargement rate was also observed, but the variations were of a smaller magnitude. With some exceptions, the lower rates of fruit enlargement occurred during hot periods, with air temperatures of 96 degrees F, or more. This suggested that the evaporating power of the air during hot periods had, by increasing water loss from the leaves, decreased water supply to the fruits to the extent that rate of fruit enlargement was checked.

Evaporating Power of the Air and Fruit Enlargement

Evaporating power of the air was measured in 1934 by a U. S. Weather Bureau type A land pan and also by black and white porous cup atmometers (7). Water losses from the evaporation pan and the white atmometer are shown in Fig. 1.

The fluctuations in water loss from the white atmometer are of greater magnitude and do not always agree with the fluctuations in water loss from the evaporation pan. This seems due to a greater sensitivity of the atmometer to air temperature and wind effects. The extremes in water losses, indicating evaporating power of the air, by the atmometer show a closer relation to maxima and minima of fruit enlargement rate than do losses by the evaporation pan, but both records show the large daily variations in evaporating power of the air that may occur during the growing season.

Of the 13 minima (numbered in Fig. 1) in rate of fruit enlargement for Plot E, all but three (Nos. 2, 5, and 11) occurred almost simultaneously in Plot G. Thus the fruit in both plots was presumably influenced by the same factors. Minima Nos. 1 and 3 occurred during periods of unusually cool weather (air temperatures from 34 to 67 degrees F), and were probably the result of this weather condition. Minimum No. 4 is not readily explained. Minima Nos. 6, 7, 8, 9, 10, and 13, for fruit in both Plots E and G, occurred during periods of very high evaporating power of the air. Although minima Nos. 7 and 10 in Plot E occurred during minima in available soil moisture just preceding an irrigation, corresponding minima in Plot G followed by increased rate of fruit enlargement indicate that these minima in Plot E, as well as those in Plot G, show the effect of evaporating power of the air as well as the effect of a decreased amount of available soil moisture. Minima Nos. 5 and 11 in Plot E were not shown by Plot G. Minimum No. 5 was apparently the result of increased evaporating power of the air, whereas minimum No. 11 was probably due to the decreased amount of available soil moisture in Plot E.

Twelve maxima (lettered in Fig. 1) in rate of fruit enlargement occurred in Plot E. In general, simultaneous but smaller maxima occurred in Plot G. Maxima A, C, E, F, G, Ha, I, K and L occurred in both Plots E and G; (with a maximum in Plot G on July 28 corresponding to an increasing rate of fruit enlargement in Plot E) and were apparently the result, at least in part, of relatively low evaporating power of the air. Maximum D, like minimum No. 4 is not readily explained. Maxima E, H-Ha, and J-Ja, although perhaps partially due

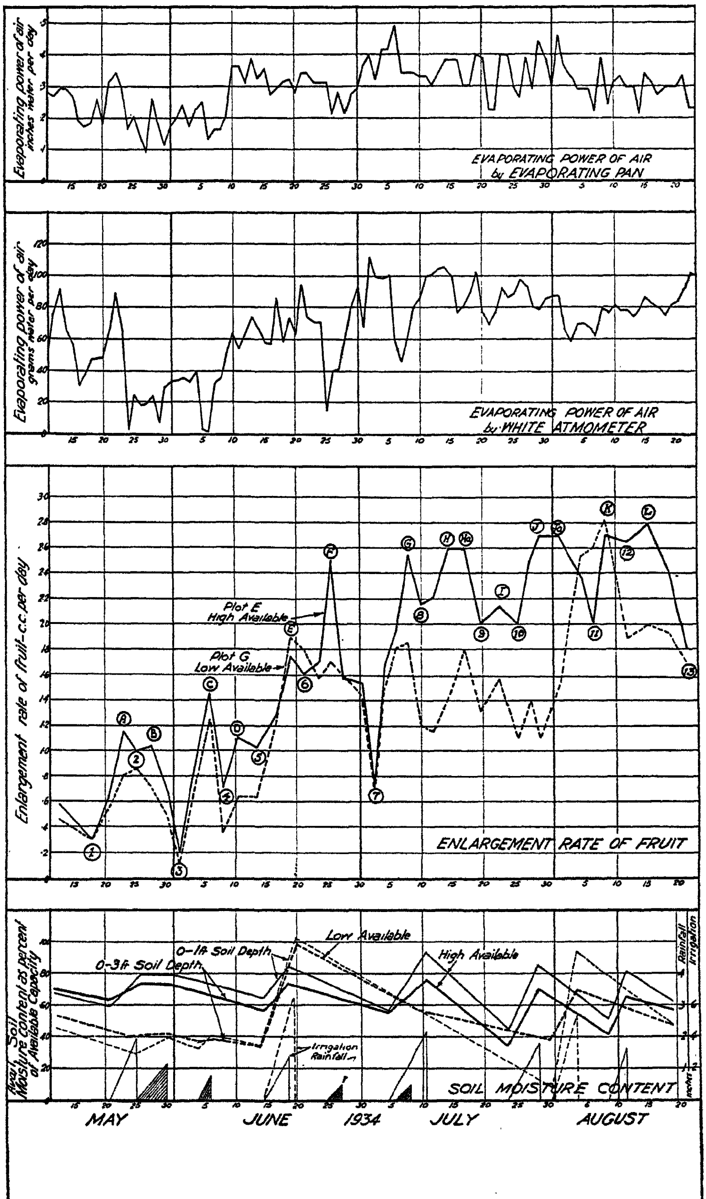

Fig. 1. Comparison of rate of fruit enlargement with evaporating power of the air and amount of available soil moisture.

to reduced evaporating power of the air, undoubtedly resulted in a large measure from the greatly increased amounts of available soil moisture at those periods.

The tendency, thus shown, is toward an inverse relation between the curve for evaporating power of the air measured by the white atmometer and the curves for fruit enlargement in both Plots E and G. This strongly suggests that evaporating power of the air influenced the rate of fruit enlargement. Both these and previous results (6) show that on heavy clay soil rate of fruit enlargement is sensitive to the amount of available soil moisture and is therefore an index of water availability to the tree. Thus high evaporating power of the air apparently affected water availability to the tree. Therefore it would seem that the rate of water loss from the tree by transpiration exceeded the rate of water supply from the soil. This would place the limiting factor in water supply in the soil, the roots, or the trunk and limbs.

However, since rate of fruit enlargement is sensitive to differences in available soil moisture, the limiting factor in water supply to the fruits is indicated as being in the soil or in the water absorbing root surface, rather than in the trunk or limbs. This conclusion is supported by the results of Aldrich, Work and Lewis (3), showing that in this soil the rate of moisture decrease was closely correlated with the concentration of small, visible roots of these trees. Root concentration for these trees was found (3) to be, in the upper 3 feet (containing about 89 per cent of the roots above bedrock), 4.5 grams of roots less than 2 mm in diameter per cubic foot. Apparently, then, water withdrawal from the soil is limited by the amount of small roots, or more specifically, by the amount of water absorbing area of the roots and root hairs, or by the distance through which water must move to reach the roots.

Top-Root Ratio

If, for these pear trees, in heavy soil, the rate of water loss by transpiration through the leaves is greater than the rate of water intake by the roots, changing the ratio of leaf area to root area (or in other words, changing the top-root ratio) should alter some of the conditions regulating the water supply to the leaves and fruit. To study the effects of such changing of the top-root ratio upon the water supply to the leaves and fruits, additional experiments were conducted in 1934.

Six, moderately vigorous, bearing Anjou pear trees were selected. The soil, classified as Medford loam, was relatively heavy, but lighter than the Meyer clay adobe previously discussed. Twenty fruits on each of these six trees were measured three times a week, beginning May 1. From counts of total fruits and total leaf clusters on each tree, it was found that leaf-fruit ratios for individual trees varied from 60 to 108. With the fruit growth rate during 2 weeks in May and the leaf-fruit ratios as a basis, the six trees were divided into three nearly comparable pairs.

Root distribution and concentration was determined from two trenches, one for each of two comparable trees, adjacent to the plot

trees in the manner previously reported (3). Root concentration was about the same from the trunk out to 11.5 feet, a point midway between the trees. Eighty-one per cent of the small roots were in the upper 6 feet. The highest root concentration found was between 6 and 12 inches deep and was 8.5 grams per cubic foot. The average root concentration for the upper 6 feet was 2.7 grams per cubic foot.

On May 28 every fifth leaf and every fifth fruit was removed by hand from one pair of trees, using the pair with the lowest initial rate of fruit enlargement. Thus one-fifth of the leaf area was removed, but the leaf-fruit ratio (leaf-fruit ratio = 67) was kept the same. This pair of trees is hereafter termed "Leaf Removal". On May 29 an estimated one-fifth of the root area was removed from another pair of trees (those with the highest initial rate of fruit enlargement) by digging a straight narrow trench, 6 feet deep, and 24 feet long, beside each tree at a distance of 5 feet 7 inches from the trunk. Since both Auchter (1) and Furr and Taylor (5) have shown that there is a ready cross transfer of water throughout the tree, removal of roots on one side of a tree should affect the water supply to all parts of the tree equally. This pair of trees (leaf-fruit ratio = 86) is called "Root Removal". The remaining pair of trees (leaf-fruit ratio = 72) was left untouched, and is termed "Normal". The average rate of fruit enlargement for each pair of trees, before and after top-root ratio changes, is plotted in Fig. 2.

For each of the six trees soil moisture determinations were made in 1-foot increments from the underside of the mulch to a depth of 6 feet in each of ten holes at each sampling. Permanent sampling locations, were duplicated for each tree at distances of 4, 7.5, 10, 11.5, and 13 feet from the trunk. The sampling locations relative to the trunk were similar for all trees. They were so located that severing of the roots of the two "Root Removal" trees at a later date did not necessitate changing the location of any hole. No sampling location was placed on the opposite side of the trench from the tree trunk.

Samples for soil moisture determinations were taken nine times, averaging 10 days apart, from May 7 to August 8. Field capacity and permanent wilting percentage determinations were made in a manner somewhat similar to that described by Work and Lewis (8). Average moisture content of the upper 3 feet expressed as per cent of the available capacity of the soil, for each pair of trees in each treatment, is shown in Fig. 2.

On June 5 basins were constructed around each of the six trees and water admitted to the basins on June 5, 6, and 8 until an estimated total of 15 inches was applied. This was estimated as sufficient to wet the entire upper 6 feet (containing 81 per cent of the roots) to field capacity. The first sampling after irrigation showed that water had penetrated to some depth below 6 feet. No further water was applied to the plots during the rest of the summer.

Rate of fruit enlargement:—The rate of fruit enlargement was about the same for each group of trees, both before and immediately after alteration of the top-root ratio. After July 1, however, the rate of fruit enlargement for Root Removal was somewhat less than that for either Normal or Leaf Removal. Leaf Removal showed a slightly

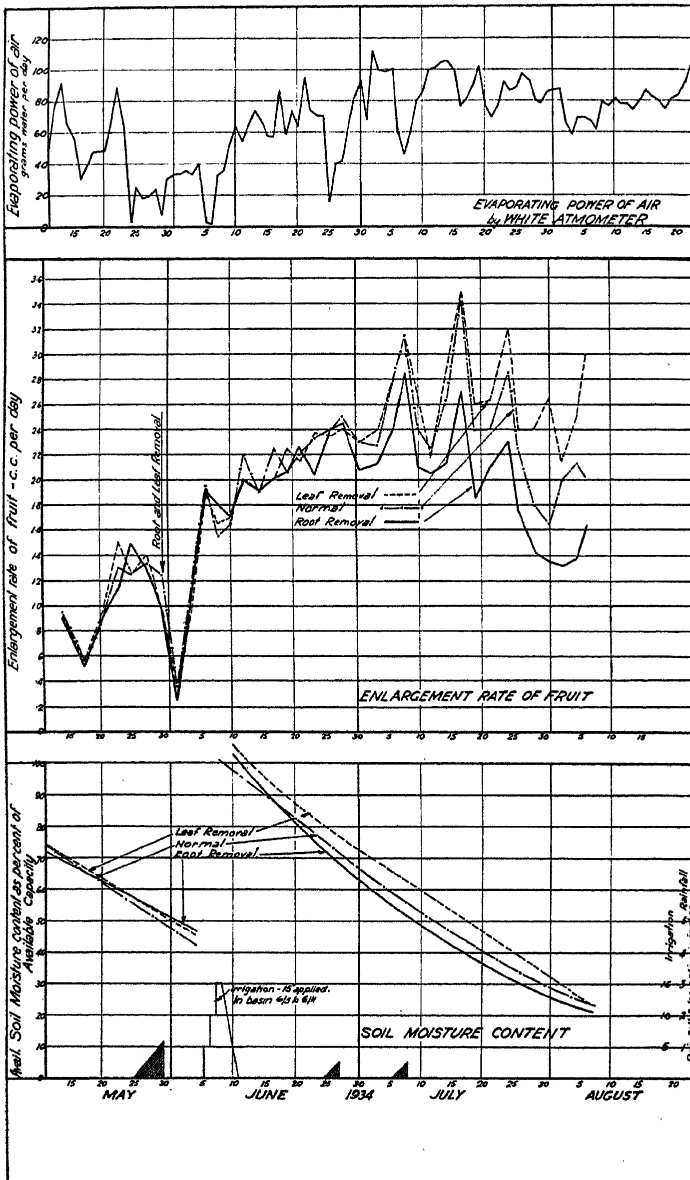

FIG. 2. Effect of Leaf Removal, Normal, and Root Removal treatments upon rate of fruit enlargement, with known conditions of evaporating power of the air and soil moisture.

greater rate of fruit enlargement than Normal after July 18. However, the early small differences in rate of fruit enlargement between different top-root ratios makes it advisable to determine the earliest period of statistically significant differences between treatments. Therefore, the average rate of fruit enlargement with the probable error of the average, is given in Table I for six critical periods.

TABLE I—EFFECT OF LEAF REMOVAL, NORMAL, AND ROOT REMOVAL TREATMENTS UPON RATE OF FRUIT ENLARGEMENTS DURING SIX PERIODS

Treatment	Rate of Fruit Enlargement (Cc per Day) During Six Periods					
	June 16–18	July 2–5	July 13–16	July 18–20	July 25–27	July 27–30
Leaf removal......	2.1±.05	2.4±.05	2.8±.06	2.6±.08	2.4±.08	2.4±.10
Normal...........	2.3±.05	2.2±.05	2.6±.06	2.4±.06	2.3±.09	1.8±.07
Root Removal.....	2.2±.05	2.0±.05	2.2±.05	2.0±.06	1.7±.07	1.4±.07

Rate of fruit enlargement for Root Removal was significantly less than for Leaf Removal during and after the July 2–5 period. Thus the Root Removal showed a definitely lower rate of fruit enlargement than Leaf Removal when the soil moisture in Root Removal and Leaf Removal had been reduced to 70 and 60 per cent of the available capacity, respectively. Although this difference in soil moisture probably contributed to the observed difference in rate of fruit enlargement, it is doubtful, judging from other results, (6) on clay adobe soil, if the difference in soil moisture accounts for more than 25 per cent of the observed difference in rate of growth between Root Removal and Leaf Removal. However, the higher top-root ratio in Root Removal than in Normal showed a definitely decreased rate of fruit enlargement by July 16, when available soil moisture in Root Removal (40 per cent of available capacity) was very little lower than that in Normal. Thus, although small differences in available soil moisture probably contributed slightly to the observed differences in fruit enlargement, soil moisture is regarded as of minor importance, and observed differences in rate of fruit enlargement are considered largely due to top-root ratio differences.

The lower top-root ratio in Leaf Removal as compared with Normal first showed a significantly increased rate of fruit enlargement during the July 27–30 period, when available soil moisture for Leaf Removal had been reduced to about 35 per cent of the available capacity. Except for one short period in early August, Leaf Removal continued to show (Fig. 2) a greater rate of fruit enlargement than Normal.

These results indicate that, for Anjou pear trees on French roots in relatively heavy Medford loam, decreasing the leaf surface but leaving the roots untouched definitely increased rate of fruit enlargement when available soil moisture was reduced below 35 to 40 per cent of the available capacity. Chandler (4) observed during a dry year that, with the leaf surface reduced by heavy pruning, apple trees had larger fruit. However, he reports that fruit size was not increased by removing part of the leaf surface.

dency to remain open longer, as compared with Normal, than occurred on June 16.

On July 19, during a period when fruit enlargement in Root Removal was definitely less than in Normal, the stomata of Root Removal closed much earlier than those in Normal. At this time when fruit enlargement in Leaf Removal was slightly, but not significantly, greater than in Normal, the stomata in Leaf Removal were open distinctly longer than in Normal.

On July 26, during a period when rate of fruit enlargement was still not significantly greater in Leaf Removal than in Normal, the period of stomatal opening in Leaf Removal was very definitely longer than in Normal.

Earlier results (2) for pears in heavy soil showed both increased stomatal opening and increased rate of fruit enlargement to be correlated with increased amounts of available soil moisture. The greater stomatal opening and rate of fruit enlargement of the lower top-root ratios in this study therefore indicate that all lower top-root ratios of these trees resulted in increased water supply to the leaves and fruits when the available soil moisture has been reduced to 35 to 40 per cent of the available capacity.

Summary

The inverse relation between evaporating power of the air and rate of fruit enlargement of pears on heavy soil, while soil moisture was well above the wilting percentage, suggests that during periods of high transpiration the leaves lose water at a greater rate than the water is supplied by the roots from available moisture in the soil. When for such trees the ratio of root area to leaf area was increased by the removal of leaves, the water supply to the remaining leaves and fruits was increased. From these results it would seem that for these pear trees, when the available soil moisture had been reduced to 35 or 40 per cent of the available capacity, the moisture supply to the leaves during periods of relatively high transpiration was limited by the amount of root area.

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Malling Stocks and French Crab Seedlings as Stocks for Five Varieties of Apples. I.

By W. H. UPSHALL, *Vineland Station, Ontario, Canada.*

ABSTRACT

To be published in full in the April issue of *Scientific Agriculture.*

THIS is a report on the behaviour of R. I. Greening, Melba, Delicious, Spy, and McIntosh on French Crab seedlings, and Malling stocks XVI, I, and II up to the end of the fifth year in the orchard. There are 16 trees of each variety on each stock. Malling I has given the smallest trees, French Crab seedlings have produced the largest trees in three varieties, and Malling XVI the largest trees in two varieties. In three varieties, trees on Malling II are larger than those on Malling XVI. Pruning weights show the possible reduction by pruning of (1) growth differences between trees on the various stocks, and (2) variability between trees within a given kind or treatment. Trees on French Crab seedlings which started in the orchard as very uniform trees are now just as variable as the trees on Malling XVI which started out very much less uniform. R. I. Greening and Melba are the only two varieties which have produced an appreciable amount of fruit. In both varieties, trees on Malling II have produced the most fruit with Malling I trees coming next in order. R. I. Greening trees on Malling XVI have outyielded those on French Crab seedlings, but with Melba the order is reversed. At one side of the orchard there are a few trees of the same varieties on Malling IX. This stock has induced different degrees of dwarfing in the various varieties, has given better yields per tree than any of the other stocks, and produces exceptionally well colored fruit.

Some Ash Constituents of Alternate-bearing Sugar Prune Trees

By L. D. Davis, *University of California, Davis, Calif.*

THE Sugar prune, as it grows at Davis, California, has an almost complete alternating habit. The alternation is so complete that in the off year no more than a dozen blossoms may be produced per tree. It would seem to offer especially favorable material for a study of the composition of the tissues of trees which are naturally bearing and non-bearing.

Many of the investigations dealing with the composition of bearing and non-bearing trees or parts of trees have been concerned with fruit-bud formation. A large proportion of the data has been for various nitrogen and carbohydrate fractions. Hooker (4), Kraybill et al (5), and Potter et al (8) have reported data for some of the ash constituents of bearing and non-bearing apple trees or bearing and non-bearing portions of the same tree. Murneek (7) has analyzed the root, stem, and leaves of fruiting and non-fruiting tomato plants for certain ash constituents. Lilleland (6) has presented data regarding the amount of calcium, magnesium, phosphorus, and potassium in leaves of bearing French prune trees and of trees that had been defruited early in the season.

A description of the trees and the methods of sampling and preservation of material has been given in a previous paper (3). The data for ash, calcium, magnesium, and potassium in 1928 are given as percentage dry weight, in Figs. 1, 2, 3, and 4. The data for the phosphorus content of the 1928 samples have been reported by Compton (2). The collections were not nearly so numerous in 1927 as in 1928 and, since the results were very similar to those for 1928, they are not reported in this paper.

The potassium content of all fractions shows the effect of a crop. The bark, wood, and spurs of the bearing trees were higher in potassium until about the latter part of March (2 weeks after full bloom). At this time, the potassium content of the bearing trees fell below that of the non-bearing and remained there for the balance of the season. The leaves of the bearing trees were consistently lower in potassium than those of the non-bearing. The bark and wood of both groups seemed to show a minimum about the time that the bearing and non-bearing trees reverse their relationship in potassium content. Calcium in the bark and spurs of the bearing material is higher than in the non-bearing. In the wood the amounts present are not large and the differences are likewise very small. The bearing wood is consistently lower in calcium than the non-bearing, a situation that is the reverse of that of the bark.

The amount of magnesium is small and there seems to be no difference in the amount in the bark, wood and spurs of bearing and non-bearing trees. Calcium in the leaves of the bearing trees is higher than in the leaves of the non-bearing trees. These two elements likewise show a very distinct seasonal change. The calcium content in-

creases from four to six times and magnesium about three times during the period of sampling.

The data for the flower buds, flowers, and fruit are given in Table I, both as percentage dry weight and as milligrams of the element per flower or fruit. The data for the milligrams of element per flower prior to March 11 were obtained by calculation. On March 4 the flowers were pushing out of the bud and on March 11 they were well out of the bud but had not opened. On these two dates the number of flowers, as well as the number of buds, were counted and the average number of flowers per bud obtained. This procedure no doubt gave data which are too high for the early samples since all portions of the fruit bud were included at that time. Relatively large amounts of each of the four elements have gone into the fruits, but the amounts of potassium and phosphorus have been especially large. If the data for January 5 be taken for a reference point, the total calcium in the individual fruit has increased about 120 times, magnesium 328 times, phosphorus 1050 times, and potassium 4375 times up to maturity of the fruit. The actual milligrams of potassium moving into each fruit have likewise been especially large.

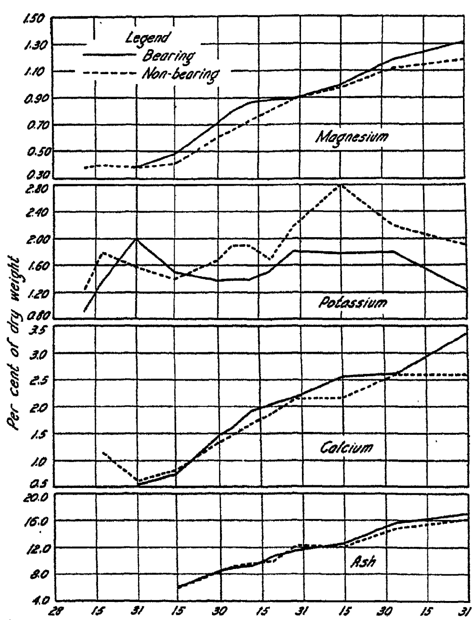

FIG. 1. Magnesium, potassium, calcium and ash, as percentage dry weight, in leaves. 1928. (Data for potassium from Master's problem of O. C. Compton.)

These data are not uniformly what might be expected. The ability of a fruiting spur of apple to mobilize within its tissues a higher concentration of nitrogen than a non-fruiting spur has been shown rather consistently by a number of investigators. Potter et al (8) have called attention to this fact and have presented data regarding the rate of movement of nitrogen into the fruit. They have suggested that enough nitrogen from this stream was moved into and deposited in the spur to give it an average nitrogen concentration higher than that of the non-bearing spur. The rate of movement of nitrogen into the fruit was from 0.5 to 1.0 mg per day. Data for wood, bark, and spurs of Sugar prunes (3) have shown that these fractions were consistently lower in N in the bearing trees than in the non-bearing trees. The rate of movement of nitrogen per fruit was never so great in the

Sugar prune as it has been shown to be in the Oldenburg apple. In the prune it varied from about 0.2 to 0.8 mg per day from the time of petal fall until the fruit was ready for harvest.

Hooker (4) has presented data regarding the potassium and phosphorus content of bearing and non-bearing apple spurs. In one case (Jonathan), the spurs were taken from the same tree; in another, (Ben Davis) they were taken from two different trees, one of which was in the on-year, the other the off-year. In the four samples taken between May and September, the bearing spurs of the Jonathan were consistently higher in potassium than the non-bearing spurs. The data for potassium in Ben Davis, and phosphorus in both varieties, do not show differences that are definite. The data for phosphorus in the Sugar prune reported by Compton (2), and that for potassium herein reported, show consistent differences between bearing and non-bearing trees. The bearing trees have a higher content of both of these elements than the non-bearing until the last of March, which is just after petal fall; at this time the content of the non-bearing trees becomes higher and remains there for the remainder of the season. The higher content of the bearing trees prior to petal fall is no doubt the result of storage of potassium and phosphorus from the previous year, when they were non-bearing. Although there is a considerable movement of these elements, particularly potassium, into the fruit, it does not result in a higher concentration in the tissues through which it must move. The actual amounts of calcium and magnesium which move into the fruit are not very different from the amount of phosphorus, yet the relationship of the calcium and magnesium of bearing and non-bearing spurs is different than that for phosphorus.

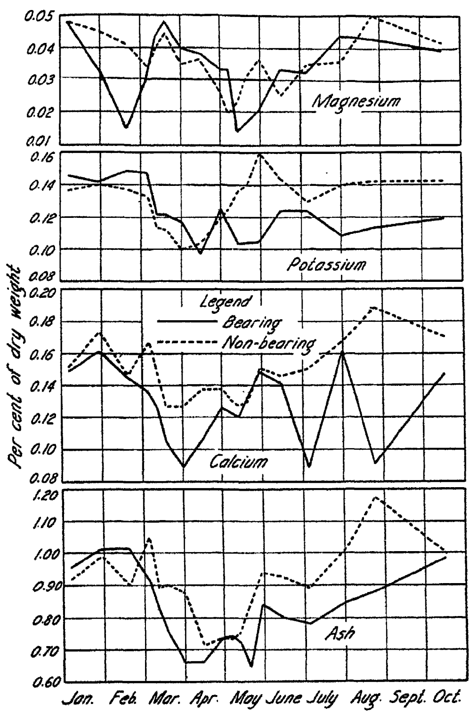

FIG. 2. Magnesium, potassium, calcium, and ash in wood as percentage dry weight. 1928.

It would seem that the production of a crop may not affect the amount of different elements in the same way, or the effect upon the

concentrations of the same element may be different in different parts of the tree. Compton (3) has reported relatively large differences between bearing and non-bearing Sugar prune trees in the phosphorus content of wood, bark, and spurs, yet the leaves of these same trees showed no differences, except when expressed as milligrams per leaf; the non-bearing leaves were larger. On the other hand, Lilleland (6) has found large differences in the phosphorus content of the leaves of fruiting and non-fruiting French prune trees, even when expressed as percentage dry weight. The non-fruiting trees were produced by removing the crop early in the season. In the Sugar prune a crop of fruit has resulted in a lower potassium content of the leaves of the bearing trees, whereas the calcium and magnesium content of the leaves of the trees is greater than in leaves of non-bearing trees. The inverse relationship of calcium and potassium in the plant has frequently been reported when these elements were present in different amounts in the culture medium. In this case the inverse relation would seem to be due to the effects of a crop since the situation is reversed in the same trees, depending upon whether they were bearing or non-bearing.

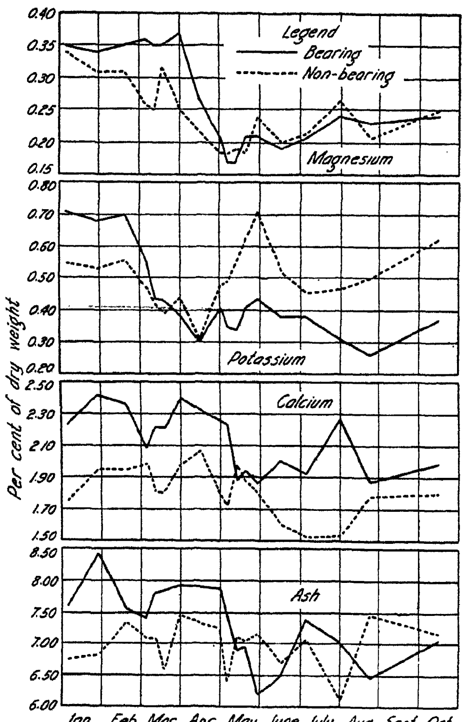

FIG. 3. Magnesium, potassium, calcium, and ash in bark as percentage dry weight. 1928.

Some evidence has been offered by Chandler, Hoagland, and Hibbard (1) that analyses of the leaves of fruit trees may not show the same relative concentrations of certain elements as do other portions of the tree. These investigators found that there were no differences in the zinc content of leaves from trees that were affected with little leaf and those that were not, yet shoots which bore these leaves showed a lower zinc content for the ones which were affected with little leaf than those that were free of the trouble.

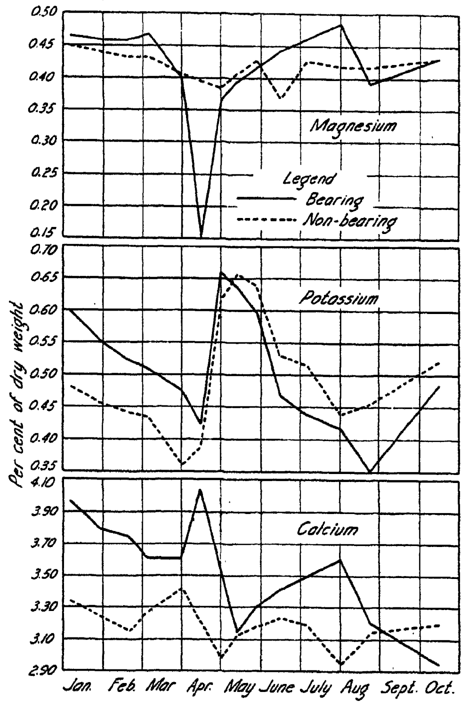

FIG. 4. Magnesium, potassium, and calcium in spurs as percentage dry weight. 1928. (Data for potassium from Master's problem of O. C. Compton.)

The data presented in this paper would seem to offer additional evidence that analyses of one portion of a tree may not adequately express relative quantities of an element or compound in another part of the tree. The failure of the data for the Sugar prune to agree with that for the apple may be due to inherent differences in the two fruits. The data of Lilleland (6) are for defruited and fruiting French prune trees, while the comparison in the Sugar prune was between normally alternating trees. It may be that this fact has caused the lack of agreement in the phosphorus content of the leaves, or inherent differences may be the determining factor, although they are closely related. The Sugar prune is a seedling of the French.

TABLE I—CALCIUM, MAGNESIUM, POTASSIUM, AND PHOSPHORUS IN FLOWERS AND FRUIT, 1928

Date	Per cent Dry Weight				Mgs per Flower or Fruit			
	Ca	Mg	K	P	Ca	Mg	K	P
1/5	1.59	0.40	0.52	0.161	.037	.009	.012	.004
1/28	1.51	0.34	0.60	0.168	.033	.007	.013	.004
2/19	1.14	0.31	1.02	0.246	.032	.008	.028	.007
3/4	0.68	0.26	1.79	0.383	.039	.015	.102	.022
3/11	0.54	0.23	1.99	0.422	.054	.025	.201	.043
3/17	0.66	0.51	1.62	0.300	.127	.098	.312	.058
3/31	0.57	0.37	1.74	0.433	.104	.067	.316	.079
4/14	0.37	0.30	1.73	0.357	.131	.106	.613	.126
4/30	0.30	0.19	1.54	0.189	.877	.556	4.50	.553
5/5	0.28	0.17	1.54	0.172	1.34	.813	7.38	.823
5/12	0.24	0.15	1.41	0.156	1.79	1.12	10.52	1.15
5/19	0.21	0.13	1.32	0.148	2.33	1.44	14.7	1.64
5/28	0.18	0.12	1.45	0.148	2.57	1.71	20.7	2.11
6/15	0.12	0.17	1.03	0.110	3.08	4.36	26.4	2.82
7/4	0.10	0.16	1.22	0.110	3.33	4.84	36.9	3.33
7/31	0.088	0.059	1.05	0.084	4.4	2.95	52.5	4.2

Summary

Data are presented for the ash, calcium, magnesium, and potassium content of alternate bearing Sugar prune trees. Attention is called to the fact that the production of a crop affects the content of different elements differently. A crop reduces the potassium and phosphorus content of the wood, bark, and spurs, but in the leaves only the potassium.. There are no differences in the phosphorus content of the bearing and non-bearing leaves. The calcium and magnesium content of bearing leaves is higher than that of non-bearing ones. The data for the Sugar prune do not agree with that for the apple, nor with data on phosphorus in the leaves of fruiting and non-fruiting French prune trees. It is suggested that the data published here add additional evidence that analyses of one portion of a tree may not adequately express the relative quantities present in its other parts.

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Seasonal Changes in Bartlett Pear Leaves

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IN the course of our investigations dealing with the black-end of Bartlett pear, data concerning certain constituents of the trees have been obtained throughout the growing season. That portion of the data which has to do with the seasonal changes of certain ash constituents and total nitrogen in the leaves is reported in this paper.

A large number of investigations have been reported concerning the seasonal changes that occur in the leaves of plants. Much of the interest has been centered around the changes which occur during the course of autumnal yellowing. Only the more recent investigations will be referred to here. Echevin (2, 3) has presented an extensive review of the earlier investigations and has summarized the data regarding the behavior of a number of different elements, particularly during the yellowing of the leaves. There seems to be rather general agreement that calcium and silica accumulate in the leaves throughout the entire season. There is a migration of potassium and phosphorus during yellowing. The data of the various investigations are conflicting regarding the behavior of sulphur, sodium, and magnesium. A large proportion of these data have been calculated on the basis of dry weight. Echevin (2, 3) has criticised this method of calculation and has shown that results calculated on the basis of dry weight may not be the same as when calculated on a basis of equal areas. His data show that during yellowing there is a decrease in the ash and calcium content of the leaves in five of six species studied when the results were expressed on the basis of equal areas of leaves, but an increase when expressed as percentage dry weight. He found a migration of nitrogen and phosphorus but no change in sulphur. A heavy loss of nitrogen occurred in the 15 to 20 days just prior to leaf fall. In a more recent paper Echevin (4) has reported a loss of phospholipides coincident with the loss of chlorophyll.

Murneek and Logan (8) have reported data concerning the autumnal migration of nitrogen and carbohydrates in the apple tree. They report a decrease of nitrogen from the leaves from the time active growth has ceased until complete defoliation has occurred. These amounts varied from 22 to 40 per cent, depending upon the time of abscission. Lincoln (6) has found a large decrease in the nitrogen content of Bartlett pear leaves. Denny (1), who investigated the changes in total nitrogen and carbohydrates in Viburnum and Syringa leaves in the period before frost, he reported a definite loss of nitrogen from the leaves of Viburnum, which underwent autumnal coloration. The nitrogen losses from Syringa were small and of doubtful significance. The leaves of the latter plant remained green until the end of the experiment. Michel-Durand (7) compared the amount of sulphur, potassium, nitrogen, and phosphorus in green leaves and fallen leaves of the chestnut and the cherry-laurel, an evergreen. By comparative figures he showed that there was a relatively large loss of potassium and nitrogen from both types of leaves. The chestnut lost much phosphorus and

little sulphur, whereas the cherry-laurel lost little phosphorus and no sulphur.

The leaves used in this investigation were taken from spurs 2 or 3 years old. These spurs had borne no fruit, and in most cases had set a fruit-bud in the year of the collection. The leaves on five spurs from each of 12 trees were taken for each collection. All the leaves from a spur were taken at each sampling. The same trees furnished the leaves throughout any one season. They were brought to the laboratory, counted, washed to remove adhering dirt, and dried in a ventilated oven at about 60 degrees C.

Aliquots from the ground leaf powder were ashed for 3 hours in an electric muffle at about 625 degrees C. After removal of the silica, calcium, magnesium, and potassium were determined. Calcium was determined by precipitation with ammonium oxalate in an HCl solution, slightly acid to methyl red, and titrated with $KMnO_4$. Magnesium was determined as $Mg\ (NH_4)\ (PO_4)$. Potassium was determined as potassium chloroplatinate. In 1931 and 1932 a separate ashing was used for the phosphorus determination. One cc of 10 per cent $Mg\ (NO_3)_2$ was added to the leaf sample before ashing. This precaution was found to be unnecessary for phosphorus in these pear leaves. In 1934 phosphorus was determined on the same sample as the other ions. Phosphorus was determined by the colorimetric method of Fiske and Subbarow (5). Total nitrogen was determined by the Kjeldahl-Gunning method.

In 1931 samples were collected from three groups of trees in one orchard (Toepelman) in the pear-growing section of the Sacramento river. One group was from trees that were 50 years old or older and were growing on *Pyrus communis* rootstock. The other two groups were planted in 1915 on *Pyrus serotina* rootstock. One group consisted of trees that had never produced any black-end fruits (Jap N in the tables) ; the other group consisted of trees that had regularly produced a high percentage of black-end fruits (Jap B in the tables). In 1932 samples were collected from an additional orchard (Elliott) located in another part of this area. The groups of trees were similar to those in the first orchard with respect to age, rootstock, and performance. In each case the block of French rooted trees was adjacent to that containing the Japanese rooted trees so that in each orchard the trees furnishing the samples were not far apart. In 1934 the samples were taken from the three groups in the Toepelman orchard and from Bartlett trees about 12 years old growing on quince root at the University Farm at Davis.

The importance of the bases used for expression of results in an investigation such as this has been emphasized (1, 2, 3). Lincoln (6) found that fresh weight, dry weight, and leaf area were equally satisfactory for picturing the migration of nitrogen from Bartlett pear leaves. Experience in our laboratories has shown that perfectly uniform sampling of mature bearing trees is a rather difficult task. We have found that the method of sampling described above in which all the leaves are taken from a given type of spur has given satisfactory samples. A sample of this kind will contain 350 to 400 leaves. There were not enough spurs on the trees on quince root for this

kind of sampling. Accordingly, about 350 basal leaves on current season's growth were taken. In Table I are presented data for the average green weight and the average dry weight per leaf for the samples taken in 1934. These data show the variations in leaf weight and in all probability leaf area which occur in this method of sampling.

TABLE I—AVERAGE GREEN AND DRY WEIGHT OF LEAF SAMPLES. 1934

Date	French Root (Mgms per Leaf)		Jap N Root (Mgms per Leaf)		Jap B Root (Mgms per Leaf)		Quince Root (Mgms per Leaf)	
	Green	Dry	Green	Dry	Green	Dry	Green	Dry
9/20......	440	190	486	206	468	226	667	328
10/2......	400	175	433	209	435	208	643	306
10/15.....	425	201	433	211	464	224	650	306
10/26.....	432	188	457	207	486	228	553	267
11/5......	460	198	484	232	470	216	543	273
11/23.....	413	200	470	232	—	221	426	242
11/30.....	450	183	497	218	526	228	602	261
12/4......	403	173	452	212	457	211	533	245
12/13.....	—	180	—	219	—	211	—	—

Leaves were not available for a representative sample from the quince block for the last sample. This sample was collected in a rain, and a value for green weight was not obtained.

The data for ash, calcium, magnesium, potassium, phosphorus, and nitrogen are presented in the following tables. The data are calculated as percentage dry-weight and as milligrams per leaf. Since the relationship between the data on a dry weight basis and as milligrams per leaf is uniform for all 3 years, only that for milligrams per leaf has been given for the 1934 data.

The data for 1931 and 1932 are presented in Table II. In 1931 the trees were in full bloom about March 20. There was a rapid increase in the average weight per leaf between April 17 and 28. The leaves did not attain their full weight until about June 1. On a dry-weight basis there was a rather large accumulation of calcium throughout the season. Magnesium was present in small amounts. The amounts of magnesium were irregular, but there seemed to be an accumulation of this element in the leaves when the whole season was considered. Potassium decreased during the period of the first two samplings, then remained more or less constant until near the end of the season, when it decreased rapidly. Phosphorus decreased rapidly during the first two samplings, then remained more or less constant throughout the season. Nitrogen decreased from the first to the last sample. The rate of loss was especially rapid between the last two samples. The data for milligrams per leaf (not presented here) were essentially like that on a dry-weight basis, after the leaf had reached full size.

The data for the Toepelman and Elliott orchards for 1932 show essentially the same seasonal changes as do those for 1931.

Inasmuch as the samples were not taken primarily to show seasonal changes, the samples taken during the latter part of the seasons of 1931 and 1932 were not complete. Accordingly, samples were taken at frequent intervals in 1934 from September 20 until December 13, at which time a large proportion of the leaves had fallen. These data should show the changes that take place during the period preced-

TABLE II—Calcium, Magnesium, Potassium, Phosphorus, Nitrogen, and Ash in Bartlett Pear Leaves. 1931 and 1932

Date	Ca			Mg			K			P			N			Ash		
	French	Jap N	Jap B	French	Jap N	Jap B	French	Jap N	Jap B	French	Jap N	Jap B	French	Jap N	Jap B	French	Jap N	Jap B
1931—Toepelman Orchard (Percentage Dry Weight)																		
4/17....	1.01	.79	.827	.437	.337	.352	2.48	2.11	2.10	.356	.334	.336	—	2.98	3.24	7.80	6.70	6.72
4/28....	1.16	1.28	1.22	.370	.373	.381	2.02	1.74	1.66	.235	.239	.237	2.74	2.32	2.47	7.23	6.92	6.79
5/25....	1.42	1.76	1.53	.423	.485	.520	1.29	1.26	.863	.210	.199	.173	2.24	2.18	2.25	6.20	6.62	5.70
6/4.....	1.62	1.91	1.81	.461	.528	.498	1.10	.696	.613	.185	.166	.163	2.15	2.17	2.23	6.26	5.98	5.56
6/24....	1.85	2.14	2.17	.451	.578	.618	1.24	.646	.825	.214	.178	.160	2.25	2.17	2.26	7.03	6.33	6.19
7/24....	1.91	2.45	2.48	—	.570	.665	1.12	.778	.807	.163	.213	.151	1.78	1.75	1.82	6.33	6.97	6.80
8/7.....	2.38	2.48	2.48	.418	.535	.581	1.36	1.21	.993	.191	.177	.161	1.73	1.72	1.68	7.04	7.65	7.03
9/23....	2.35	3.16	2.78	.470	.652	.715	1.20	.895	.930	.230	.189	.228	1.68	1.67	1.67	7.38	8.21	8.02
10/15...	2.61	3.17	3.00	.512	.667	.668	1.09	.821	.945	.233	.250	.222	1.49	1.58	1.64	7.75	8.29	8.23
12/4....	3.10	3.33	3.48	.562	.601	.642	.489	.707	.662	.188	.191	.186	.80	1.08	1.06	9.41	10.5	10.5
1932—Toepelman Orchard (Percentage Dry Weight)																		
5/26....	1.54	1.74	1.52	.373	.570	.533	1.32	.778	.777	.205	.180	.169	2.19	2.26	2.28	5.92	5.33	4.91
6/16....	1.73	1.88	1.83	.370	.593	.593	1.31	.802	.720	.193	.163	.171	2.16	2.02	2.04	7.34	6.16	6.55
8/10....	2.06	2.57	2.56	.411	.703	.643	1.30	.730	.787	.192	.170	.159	1.81	1.76	1.72	7.79	8.40	8.77
10/4....	2.32	2.80	2.77	.502	.801	.742	1.67	.384	.547	.222	.197	.274	1.72	1.65	1.45	8.15	7.23	7.30
11/17...	2.45	2.94	3.27	.433	.697	.620	1.07	.421	.608	.257	.144	.135	1.36	1.52	1.47	7.73	7.36	7.83
1932—Elliott Orchard (Percentage Dry Weight)																		
5/26....	1.65	2.20	2.16	.424	.479	.512	1.61	1.61	1.49	.251	.270	.267	1.96	2.24	2.03	6.87	8.85	7.61
8/10....	2.35	2.29	2.89	.560	.503	.559	.797	1.27	1.26	.211	.223	.260	1.90	1.86	1.78	7.92	8.30	9.91
10/4....	2.50	2.24	3.24	.558	.456	.610	.880	1.40	1.41	.264	.271	.320	1.61	1.51	1.56	7.39	7.90	9.35
11/17...	3.20	3.85	3.56	.546	.680	.581	.698	.809	1.15	.237	.184	.244	1.14	.94	.89	8.24	9.40	9.76

ing and during leaf fall. Distinct yellowing of the leaves began about November 23 and became more pronounced in the succeeding samples. The leaves on these latter dates seemed ready to fall, from the ease with which they could be detached from the spurs. The leaves in the last sample were almost completely yellow and would fall with the slightest disturbance. The collections have been made frequently

TABLE III—CALCIUM, MAGNESIUM, POTASSIUM, PHOSPHORUS, NITROGEN, AND ASH IN BARTLETT PEAR LEAVES. 1934

Date	French	Jap N	Jap B	Quince	French	Jap N	Jap B	Quince	French	Jap N	Jap B	Quince
	(Percentage Dry Weight)											
	Ca				Mg				K			
9/20	2.48	2.81	2.78	2.64	.45	.69	.66	.83	1.47	.60	.63	.75
10/2	2.45	2.94	2.83	2.59	.41	.69	.66	.83	1.40	.56	.64	.77
10/15	2.59	2.92	2.82	2.76	.41	.69	.64	.83	1.27	.51	.67	.83
10/26	2.54	2.85	2.76	2.88	.44	.66	.61	.85	1.39	.58	.64	.78
11/5	2.61	2.36	2.87	2.92	.41	.65	.64	.86	1.27	.52	.62	.64
11/23	2.74	3.07	2.94	2.93	.38	.63	.59	.83	1.13	.47	.53	.59
11/30	2.64	2.99	2.80	3.09	.37	.59	.58	.88	1.06	.41	.57	.52
12/4	3.04	3.08	2.91	3.00	.40	.58	.59	.81	.87	.43	.56	.56
12/13	3.22	3.26	3.12	—	.38	.64	.60	—	.93	.34	.46	—
	(Percentage Dry Weight)											
	P				N				Ash			
9/20	.24	.18	.16	.12	1.64	1.76	1.70	1.71	8.58	8.60	7.54	9.10
10/2	.23	.18	.16	.13	1.63	1.52	1.58	1.70	7.98	7.56	7.43	7.52
10/15	.22	.16	.18	.13	1.59	1.49	1.57	1.65	7.96	7.53	8.08	8.32
10/26	.23	.18	.18	.12	1.52	1.52	1.54	1.52	9.32	9.17	9.77	11.0
11/5	.23	.18	.18	.12	1.57	1.51	1.53	1.52	8.18	7.66	8.05	9.18
11/23	.23	.19	.16	.11	1.51	1.53	1.56	1.48	8.72	9.16	8.12	8.42
11/30	.21	.16	.16	.09	1.19	1.34	1.32	1.06	7.81	7.52	7.44	8.39
14/2	.20	.15	.15	.09	1.04	1.19	1.24	.92	8.69	8.23	9.45	9.80
12/13	.22	.13	.12	—	.88	.93	.93	—	8.77	7.76	8.55	—
	(Mgms per Leaf)											
	Ca				Mg				K			
9/20	4.71	5.80	6.29	8.66	.855	1.42	1.49	2.72	2.79	1.23	1.42	2.46
10/2	4.29	6.15	5.89	7.93	.717	1.44	1.37	2.54	2.45	1.17	1.33	2.36
10/15	5.21	6.15	6.31	8.45	.825	1.46	1.43	2.54	2.55	1.08	1.50	2.54
10/26	4.78	5.90	6.30	7.70	.827	1.37	1.39	2.26	2.61	1.20	1.46	2.08
11/5	5.16	5.48	6.20	7.98	.812	1.51	1.38	2.35	2.52	1.21	1.34	1.75
11/23	5.48	7.12	6.50	7.10	.760	1.46	1.30	2.01	2.26	1.09	1.17	1.43
11/30	4.83	6.51	6.39	8.06	.676	1.28	1.32	2.30	1.94	.895	1.30	1.36
12/4	5.25	6.52	6.14	7.35	.693	1.23	1.25	1.98	1.50	.913	1.18	1.37
12/13	5.80	7.14	6.60	—	.684	1.40	1.27	—	1.67	.745	.970	—
	(Mgms per Leaf)											
	P				N				Ash			
9/20	.456	.371	.362	.394	3.12	3.62	3.84	5.60	16.4	17.7	17.0	29.5
10/2	.403	.376	.332	.398	2.86	3.18	3.29	5.20	14.0	15.8	15.4	23.1
10/15	.442	.338	.402	.398	3.20	3.14	3.52	5.05	16.0	15.9	18.1	25.5
10/26	.432	.372	.410	.320	2.86	3.14	3.52	4.06	17.5	19.0	22.3	29.4
11/5	.455	.418	.389	.328	3.11	3.50	3.30	4.15	16.2	17.8	17.4	25.0
11/23	.460	.440	.354	.266	3.02	3.54	3.45	3.58	17.5	21.3	17.9	20.4
11/30	.386	.349	.365	.235	2.18	2.92	3.00	2.76	14.3	16.4	17.0	21.9
12/4	.346	.318	.316	.220	1.80	2.52	2.62	2.26	15.0	17.4	19.9	24.0
12/13	.396	.284	.253	—	1.58	2.04	1.96	—	15.8	17.0	18.0	—

We are indebted to E. A. Wilkins for the analyses of the 1934 material.

enough to give a much more accurate picture of the changes taking place prior to and during the period of yellowing than was possible from the collections of the two previous years. The data are presented in Table III.

During this period there was a gradual increase in calcium. The amount of magnesium was small and remained at about the same level, throughout the time of the sampling. Potassium decreased gradually from about the time the leaves began to yellow. Phosphorus also decreased after this time in all groups except the trees on French root. Nitrogen showed the greatest change of any of the elements examined. There was a gradual loss throughout the period of sampling. The loss became especially rapid in the periods included between the last samples.

Although the samples were not taken so that exactly equal areas of leaves could be compared with respect to the amounts of the different elements present, it is very probable that the average areas of the leaves of any group were much the same after the leaves had attained full size. If this assumption is made, the data for the amounts per leaf may be used as a basis for evaluating the absolute changes after this period. Much the same picture is presented when the data are expressed as percentage dry weight or as amounts per leaf. This is in agreement with the data of Lincoln (6). Fig. 1 compares the data for the Jap normal trees for 1934 on the basis of dry weight and amounts per leaf.

There are certain seasonal changes in the leaves of the Bartlett pear. Rather large amounts of calcium accumulate throughout the season so that at the time the leaf is ready to fall there may be as much as seven milligrams per leaf. There was no migration of this element in the period prior to leaf fall. Instead there seems to be a rather slow accumulation. Although the amount of magnesium present is small, there seemed to be a seasonal increase. If the data for 1934 are representative, the magnesium content has reached its maximum prior to the last three months the leaves are on the tree.

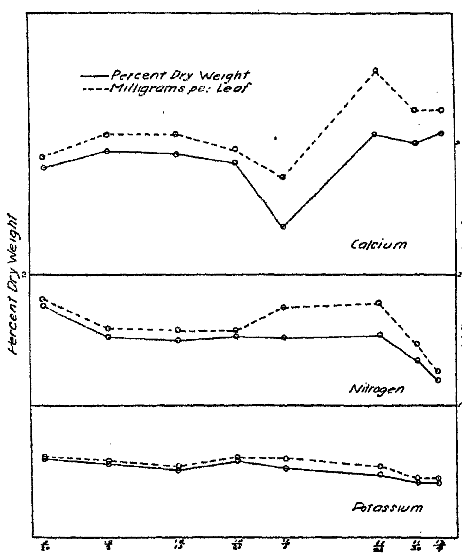

Fig. 1. Comparison of Ca, N, and K as per cent dry weight and as milligrams per leaf. Toepelman Orchard, Jap N Roots, 1934. The value for milligrams per leaf has been divided by 2 to facilitate graphing.

Potassium and phosphorus were not so uniform as the other ele-

ments in the 1931 and 1932 samples. We do not know whether this indicates a greater variability in the sampling error for these two elements or whether they are more responsive, in the leaves, to changing conditions farther back in the tree. There was a rapid drop in potassium during the earliest samplings, on a per cent dry-weight basis. On the basis of amounts per leaf there was an actual increase. Throughout much of the growing season potassium remained more or less constant, although samples were not taken frequently enough to evaluate these changes properly. There was a definite loss in the latter part of the season. If the amounts present on September 20, 1934, be considered as representative of the mid-season level in that year the loss of potassium in the leaves of the last sample varied from 27 to 43 per cent. Phosphorus behaved much like potassium during early and mid-season. There was a decrease in the phosphorus content of the leaves from the Jap N, Jap B, and quince rooted trees in 1934, but it came quite late in the season,—during the last 2 or 3 week before leaf fall. The amount lost in each of these three cases was approximately 25 per cent of that present prior to this period.

Nitrogen showed more regular and consistent changes than any of the other elements studied. There seemed to be a loss of nitrogen throughout the entire period. This loss became especially great at about the time the leaves turned yellow. Although in 1934, all four groups of trees lost about 47 per cent of their nitrogen during the period of the sampling (nearly 3 months) only about 10 per cent had been lost by November 23, when the leaves began to become yellow. The remaining 37 per cent was lost during the following three weeks.

It may be, as Echevin (3) has suggested, that no general rule can be laid down regarding the behavior of elements in leaves, and that soil conditions and even age of tree may affect their behavior. Trees of different ages growing on at least three different rootstocks on differing soil types have been used in this investigation. Yet the behavior of the various elements has been much the same in the different groups with the possible exception of P in the French-rooted trees in 1934. The trees are, however, all mature, bearing trees.

These data are probably representative of the seasonal changes of these elements in the leaves of well-grown, bearing Bartlett pear trees, unless factors such as character of the soil would produce changes that are not readily seen in the performance of the tree.

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Maturity and Quality in Acid Citrus Fruits

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ABSTRACT

The complete paper will be published in the Proceedings of the Florida State Horticultural Society. 1935.

DURING the past season preliminary maturity and quality tests on acid citrus fruits grown in the eastern humid subtropical crops region were undertaken for the following varieties: Perrine, Eureka, Meyer, and Sperryola lemons, and Key, Tahiti, Lakeland, and Eustis limes. The work was carried on during the heaviest production period, July to December.

The varietal maturity and quality was studied in terms of physical fruit characters, as weight, shape, thickness of rind, and percentage of rind, rag, and juice; number of locules, and seeds, color of rind and juice, other miscellaneous characters, and physico-chemical characteristics of the juice,—total solids, total acids, effective acidity (pH); and organoleptic or taste qualities. The technic has been described elsewhere. Samples were collected from central and south Florida groves at approximately 14-day intervals. Preliminary observations on the effect of drought on fruit composition were also made.

The usual determination of the solids (sugars) to acid ratio now used in the study of maturity and quality in oranges and grapefruit obviously does not apply here. As often used, the extracted juice undergoes considerable dilution, and the total acids present indicate the extent to which this dilution may be carried and still secure a high class product. The varieties most widely grown in Florida contain a minimum of 5 per cent acids for limes and 4 per cent for lemons. Aside from such considerations as varietal frost and disease resistance, productivity and keeping quality, the chief criteria for an ideal acid citrus fruit are concerned with percentage of acid and extractable juice. These latter are here considered briefly.

Limes:—Percentage acid. On the basis of the data secured to date, lime varieties studied may be placed into three classes on the basis of average percentage of acid in the extractable juice,—(a) Key, above 7 per cent, (b) Lakeland and Eustis with 6 to 7 per cent, and (c) Tahiti with 5 to 6 per cent.

Percentage solids. There was no great variation in percentage of total solids for all lime varieties studied, 10 to 11 per cent, excepting that Tahiti, on rough lemon rootstock, had a comparatively lower range of solids, 9.2 per cent.

Percentage extractable juice. The percentage of extractable juice was highest for Key, 53 per cent; Tahiti had from 43 to 52 per cent; Lakeland had a greater juice percentage, 50 to 52 per cent, than Eustis, 41 per cent.

Lemons:—Percentage acid. On the basis of acid percentage lemon varieties studied fall into three classes, (a) Perrine and Eureka with 6 to 7 per cent; (b) Meyer with 4 to 5 per cent and (c) Sperryola below 4 per cent.

Percentage solids. Percentages of total solids in general show trends similar to acid percentages. The use of certain rootstocks may lead to higher percentages of solids as shown by 9.5 to 10.9 per cent when Perrine is grown on rough lemon as contrasted with 12.4 per cent for the same variety on sour orange. The same variety grown on sweet lemon, Cuban shaddock, Rusk citrange and Key lime gave intermediate solids percentages, 10.5 to 11.5 per cent.

Percentage juice. Perrine from various locations had an average extractable juice percentage of 32 to 41 per cent. Eureka averaged 40; Meyer 47 to 49 per cent; and Sperryola 41 to 46 per cent.

Rainfall and acid percentage:—Under irrigated grove culture it would be expected that maturity processes would go on fairly evenly as shown in previous work in Texas. In the eastern humid subtropical crops region with the onset of the dry season in the fall, lack of moisture in seasons of drought might affect the results. The past fall and early winter were unusually dry which made it advisable to investigate any possible effect this factor might have on the results. Calculations show that there is a negative correlation between total rainfall and the amount of acid present. Perrine, (six locations in central and south Florida) $r = -0.524 \pm 0.104$; Meyer (three locations in central Florida) $r = -0.418 \pm 0.185$; Tahiti (two locations in central and south Florida) $r = -0.973 \pm 0.011$; and Lakeland (one location in central Florida) $r = -0.579 \pm 0.129$. The higher percentages of acid during periods of drought are apparently due to loss of moisture by plant tissues. This subject will be given increased attention in future work.

Sugar and Acidity Changes in Pears as Influenced by Variety and Maturity

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COMMERCIAL varieties of pears grown in the Pacific Coast region are generally harvested at a definite stage of maturity, commensurate with good storage and ripening quality, and considerably in advance of the stage known as "tree ripe." If permitted to ripen on the tree, the dessert and storage quality become drastically reduced through the occurrence of mealiness and core breakdown, with the excessive accumulation of acetaldehyde. Harvesting, storage, marketing and canning experience have shown that this type of fruit should be removed from the tree while still in a firm hard green condition.

Much thoughtful effort has been directed toward a solution of the proper maturity, storage and ripening problems associated with the handling of each variety of pears. Those interested in the harvesting and handling practices are referred to Hartman (3), Magness, Diehl and Allen (6), Allen (1) and Pentzer, et al. (8). Physiological and biochemical investigations pertaining to pear varietal and maturity problems, however, have not been studied in such detail. Magness (5), working with the Bartlett pear, has shown that sugar increases from early summer to the close of the commercial harvest season, the increase being due largely to sucrose accumulation. He also found a distinct relationship between the amount of sugar present in the ripe fruit and the storage temperature at which the fruit had been held prior to ripening; higher storage temperatures being conducive to higher sugar values in the ripened product.

Moore (7) has provided further information on the mineral constituents and the iron-copper ratio in winter pears. His results show that pears possess a high alkaline ash and should be included among those food materials which aid in maintaining a desirable acid-base balance in the diet. Although no data are presented, the same author has called attention to the large proportion of levulose sugar present in pears and its possible importance in dietary demands for diabetes mellitus.

There was published some 20 years ago a splendid short paper by Thompson and Whittier (11) on the forms of sugar found in common fruits. These authors stressed the importance of determining the different kinds of sugar present in numerous varieties of common fruit and went so far as to classify these fruits according to the dominant type of sugar present. Under their classification, apples, pears, quinces, and watermelons belong to the levulose group. They discussed the fallacy of expressing carbohydrate results in terms of sucrose and invert sugar, because reducing sugars are not always present as invert sugar, since in many fruits levulose is nearly double that of glucose. This constructive criticism led to the generally accepted procedure of expressing carbohydrate results in terms of reducing sugars, total sugars, and sucrose, with relatively little effort

being made to evaluate the reducing sugar fraction in terms of levulose and dextrose. Unfortunately the full importance of this earlier paper apparently has been overlooked in our more recent attempts to evaluate physiological response of fruit and vegetables in terms of carbohydrate analyses. Even during the past decade the preponderance of our carbohydrate literature on fruits is still being expressed under the general terms of reducing sugars, total sugar, and sucrose.

It is difficult to see why it is not of just as much importance to determine how much levulose and dextrose there might be in a fruit as it is to know the quantity of sucrose present. It is the opinion of the writers that much more value would be attached to carbohydrate studies in fruit if the different forms of free sugars were expressed according to the kinds present, i. e. dextrose, levulose and sucrose, rather than under the general terms of reducing and total sugars. Furthermore, the reducing power of glucose is considerably greater than that of fructose, and when reducing sugars high in levulose are evaluated in terms of glucose, an appreciable error is introduced in the expression of the results.

With these facts in mind, and in connection with our general studies on the physiology of pears, an attempt has been made to gain further information relative to what effect maturity and variety exert on the kinds and amounts of sugars present in pears. Furthermore, since Du Toit and Reyneke (2) have shown a definite relationship to exist between, (a) the ratio of the H-ion concentration to total acidity (which they term "Index Figure,") and (b) the ripening processes, it was deemed advisable to test their hypothesis by the incorporation of pH and total acidity determinations in the present study.

Material and Methods

Five commercial varieties of pears were chosen for this study during the 1933 season, namely, Bartlett, Flemish Beauty, Bosc, Comice and d'Anjou. Samplings for the analytical work were collected at three maturities termed early, commercial, and late. Acid and carbohydrate samples were taken from portions of 20 typical fruits, the former being frozen prior to the extraction of the juice, the latter being preserved in boiling alcohol.

Sucrose was determined by difference in copper reducing power before and after acid inversion using the Quisumbing and Thomas (9) reduction procedure and the Shaffer and Hartman (10) titration technique. Glucose and levulose were estimated by using the iodine oxidation method as outlined by Lothrop and Holmes (4). pH and total acids were measured electrometrically using a saturated calomel cell and gold electrode. The "Index Figure" represents the ratio of gram mols H ions per liter/millequivalents of H_2 per liter or in other words the ratio of dissociated to the total acid present.

Results

The data are in Table I. It will be noted all varieties of pears soften on the tree as maturity increases; the pressure values for the second picking in each case correspond rather closely to the generally accepted commercial harvest maturity. Glucose, in all varieties studied,

reached a maximum concentration in the first picking and then decreased during the remainder of the maturation period. Fructose, however, reached its maximum concentration during the second harvest period in Bartlett, Flemish and d'Anjou varieties, while in Bosc and Comice fructose increased throughout the entire harvest range. Sucrose increased rapidly after the second harvest period; Bartlett and Bosc varieties being exceptionally high in this form of sugar by the close of their harvest seasons. Evidently sucrose and fructose represent the accumulative forms of sugar in maturing pears and could have for their common source the hydrolysis of starch.

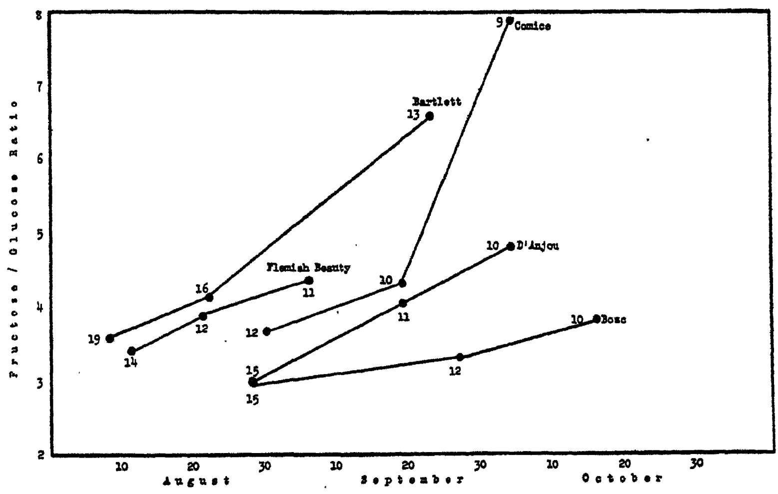

FIG. 1. Showing the ratio of fructose to glucose in certain varieties of pears at three different maturities. Numbers in the graph indicate the pressure test at each harvest period.

The value of individual expression of the kind of sugar present in fruit is illustrated in column 7 of Table I and graphically in Fig. 1. The ratio of fructose to glucose increased with maturity in all varieties studied. Furthermore, this ratio changes for the different varieties, being the highest in the case of the Comice. The increase of sucrose and fructose, both being the sweetest forms of commonly occurring sugars, together with a gradual loss of acidity offer a chemical clue for the enhancement of quality due to increasing maturity of pears.

The active acidity of the juice decreased as maturity advanced; here again varietal factors were operative, Bosc possessing much lower values. Du Toit and Reyneke (2) in their studies of the keeping quality of fruit have shown that maximum growth, sugar content and "Index Figure" occur together at that stage of ripeness which experience has shown best for commercial harvest. This value attained a maximum, and then fell, indicating a critical peak. The values in the last column of Table I indicate that, with the exception of the Bartlett variety, all "Index Figures" are highest during the second or

TABLE I—EFFECT OF MATURITY AND VARIETY ON (A) THE KIND AND PERCENTAGE OF SUGARS* PRESENT AND (B) THE ACID REACTION IN PEARS

Date Harvested	Pressure (Pounds)‡	Glucose	Fructose	Sucrose†	Total Sugars	Ratio: Fructose/Glucose	pH	Total Acids: CC N/10 NaOH 25 Cc Juice	Total Acids: Per cent as Malic	Index Figure (10^{-7})
					Bartlett					
Aug. 8	19.7	1.16	4.17	1.41	6.74	3.60	4.12	9.8	.368	19.3
Aug. 22	16.4	1.04	4.30	1.80	7.14	4.13	4.21	8.8	.315	17.5
Sept. 23	13.1	0.71	4.32	5.60	10.63	6.80	4.62	4.8	.140	12.4
					Flemish Beauty					
Aug. 11	13.9	1.11	3.82	1.51	6.44	3.44	4.31	6.7	.407	18.2
Aug. 21	11.6	1.07	4.17	2.04	7.28	3.90	4.32	5.8	.201	20.6
Sept. 6	10.8	0.80	3.79	4.43	9.02	4.37	4.71	4.5	.147	10.8
					Bosc					
Aug. 28	14.6	1.26	3.71	2.60	7.57	2.94	4.65	5.2	.221	10.7
Sept. 27	12.1	1.24	4.09	3.33	8.66	3.30	4.67	4.8	.167	11.1
Oct. 16	9.7	1.24	4.74	6.24	12.22	3.82	4.79	4.1	.158	9.8
					Comice					
Aug. 30	12.4	1.19	4.39	2.05	7.63	3.69	4.38	8.1	.288	12.9
Sept. 19	9.8	1.24	5.38	2.49	9.11	4.34	4.12	8.8	.251	21.5
Oct. 4	9.2	0.77	6.10	4.00	10.87	7.92	4.53	5.8	.207	12.7
					d'Anjou					
Aug. 28	15.0	1.35	3.94	0.76	6.05	2.92	4.19	9.7	.328	16.6
Sept. 19	11.0	1.17	4.77	2.02	7.96	4.08	4.04	10.5	.291	21.7
Oct. 4	9.7	1.03	4.59	3.20	8.82	4.81	4.18	7.7	.234	21.4

*Data calculated on the basis of original fresh weight.
†Calculated as invert sugar.
‡U. S. Pressure tester using a plunger $\frac{5}{16}$ inch in diameter.

commercial picking, and even in the case of the Bartlett, it is entirely possible that the critical peak might have occurred between the first and second pickings. These facts lend support to the contention that the "Index Figure" stands in close relationship to the maturation. processes in the fruit and, with further study, may offer a more sensitive physiological index of maturity than do our present standards.

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Storage of Yellow Newtown Apples in Chambers Supplied With Artificial Atmospheres

By F. W. ALLEN and L. R. MCKINNON, *University of California, Davis, Calif.*

METABOLIC activities of fruit are reduced to their minimum, and maximum keeping quality is usually obtained, by storage temperatures only slightly above the freezing point of the fruit. Since this, even for the more succulent fruits such as berries, usually lies below 30 degrees F (1), storage temperature of from 30 to 32 degrees F are often recommended. Even in the absence of any true freezing injury, however, storage at 32 degrees F may cause certain physiological disorders impairing the value if not the life of the fruit. Green bananas, if held below 56 degrees F, will "chill" and fail to ripen with proper color. Oranges and grapefruit will hold longer at 32 to 34 degrees than at 45 to 55 degrees, but severe spotting of the rind at the lower temperatures makes them undesirable. Grimes Golden apples, as grown in Iowa, are, according to Plagge and Maney (2), subject to soggy breakdown when stored at 30 to 32 degrees F. The Yellow Newtown apple, grown in the Pajaro Valley of California and stored at these temperatures, will develop a severe "internal browning." Though the fundamental cause is still undetermined, this browning is materially lessened by storing the apples at higher temperatures than those usually recommended. At 40 to 45 degrees the trouble could be almost eliminated. Obviously this temperature would favor scald and too rapid ripening. As a compromise, an optimum temperature of 36 to 38 degrees F has been adopted by most cold storage warehousemen. Newtown apple growers in the Pajaro Valley hope to find some means to control browning under conditions that will reduce coloring to a minimum. Buyers prefer a green color, and apples showing much yellow can usually be sold only at a discount.

In studying apple scald in the Yakima Valley, Washington, in 1918, one of the writers observed that apples sealed in cans and stored for a time with commercial packages in a 32 degrees F room remained hard and green but became so alcoholic as to be worthless. Similar results were reported by Brooks, Cooley, and Fisher (3); Magness and Diehl (4); and others. Kidd and West in England have demonstrated the commercial possibilities of CO_2 storage. Reporting on their extensive experiments (5) begun in 1918, they have shown that where CO_2 was increased and O_2 decreased, apples remained firmer and showed less color change under temperatures of 5 and 10 degrees C (41 and 50 degrees F) than did comparable samples held in air; moreover, the gas-stored samples at these temperatures surpassed air-stored samples at 1 degree C (34 degrees F).

If California-grown Newtowns would respond similarly to the Bramley's Seedling and other English varieties used by Kidd and West, they should remain hard and green-colored at a temperature above that which favors browning. This report covers the first season's work toward this end.

Materials and Methods

The apples in this test were from an individual tree in a Pajaro Valley orchard known for its poorly keeping fruit. As shown by individual tree records for two previous seasons, apples from the tree selected were especially susceptible to internal browning. The apples were harvested October 16, 1933, at an average firmness of 19.5 pounds[1]; the color varied from 1½ to 2½, mostly 2—[2]. At Davis the fruit was divided into 10 different test lots of approximately 50 apples each, each lot being carefully sorted for uniform size and color.

Five-gallon, wide-mouthed glass bottles filled to capacity were used as storage chambers for the different lots. Two of them, left open, were stored in a 36 degrees F room. This fruit, held under commercial storage conditions, served as check samples. The other eight containers were sealed with screw-top lids, through which were inserted two small pieces of metal tubing to permit gas exchange, and were stored in an adjoining room at 42 degrees F. Two of these containers were held in normal air, and two each in an atmosphere containing 5, 10, and 15 per cent of CO_2, with a corresponding reduction of O_2. All fruit was unwrapped, but had a small amount of shredded oiled paper mixed with it.

To obtain these synthetic atmospheres, air under pressure was used as a source of O_2, whereas N and CO_2 were secured from pressure tanks. At 2-minute intervals, a motor-driven mercury pump (6) (equipped with special measuring-bulbs and pipette valves) measured, mixed, and forced into each chamber, under atmospheric pressure, 200 cc of normal air and of "air" containing the desired proportions of N, O_2, and CO_2. These different atmospheres, both natural and synthetic, were continually forced in and out of the chamber, completely changing the air in about 6 hours—a rate sufficiently rapid to hold the CO_2 content in the chambers supplied with normal air under 0.3 per cent. O_2 and CO_2 determinations were made from the air passing out of the chambers. Sampling bulbs were placed and, except during sampling, maintained in the exhaust lines. At first, gas analyses were made daily; later, only two to three times weekly. Throughout the storage period of 180 days the atmospheres from the chambers remained remarkably constant. The usual fluctuation in the percentages of O_2 and CO_2 was less than 0.2 per cent. Only at the start, when the equipment needed some slight adjustment, and on one or two occasions when changing tanks of N, which varied somewhat in its composition, did these percentages vary from the desired amounts by more than 1.0 per cent.

Results

Since the fruit was unwrapped and in glass containers, observation was easy. By December 10, fruit held at 42 degrees F in normal air showed slight yellowing. No color change was apparent in any other sample.

[1]The pressure, in pounds, required to force a 7/16-inch plunger point into pared fruit to a depth of 5/16 of an inch.

[2]Figures refer to color values on a standard color chart: No. 1, green; 2, light green; 3, yellowish green; 4, greenish yellow to light yellow; and 5, full yellow.

On January 12, 1934, after 3 months' storage, one container held under each condition was opened, and half the specimens (about 25) were removed for examination and testing (Table I). The results were outstanding and consistent. The fruit stored in normal air at 36 degrees F (commercial conditions) was of optimum ripeness for eating, and half the specimens showed slight internal browning. The air sample at 42 degrees was likewise fully ripe, showing decidedly more yellow than any of the other lots, but no internal browning. The three gas-stored samples at 42 degrees exhibited much less color and more firmness than the fruit held in air. All these apples were too firm for best eating. In comparing one gas sample with another, the firmness of each lot was proportional and the color inversely so to the percentage concentration of the CO_2 supplied. Color differences could be noted without a color chart, while differences in firmness could be detected by cutting. The flesh of lots 4 and 5, stored in concentrations of 10 and 15 per cent, was slightly woody. No scald, internal browning, or off-flavor could be detected in any sample.

TABLE I—COMPARATIVE COLOR, FIRMNESS, AND CONDITION OF YELLOW NEWTOWN APPLES JANUARY 12, 1934, AFTER BEING STORED FOR 12 WEEKS IN VARIOUS CONCENTRATIONS OF CO_2

Series	Color Index*	Average Firmness (Pounds)	Percentage of Fruit Showing		Flesh	Flavor
			Internal Browning	Scald		
1. Normal air 36 degrees F	2–2½	14.0	50% slight	0	Becoming mellow	Normal
2. Normal air 40 degrees F	3½–4	13.9	0	0	Becoming mellow	Normal
3. 15 per cent O_2 5 per cent CO_2 40 degrees F	2½–3	15.7	0	0	Very firm	Normal
4. 10 per cent O_2 10 per cent CO_2 40 degrees F	2½	18.0	0	0	Very firm to slightly woody	Normal
5. 5 per cent O_2 15 per cent CO_2 40 degrees F	2–2½	18.8	0	0		Normal

*Color values: No. 1, green; 2, light green; 3, yellowish green; 4, greenish yellow to light yellow; and 5, full yellow.

On March 9 the remaining half of the fruit in the containers opened in January was removed and observed, with comparative results very similar to those of the previous inspection. Fruit in all the different chambers showed further increased color and slightly decreased firmness. Differences in firmness were even more noticeable than the pressure-test data might indicate. Both samples held in air were becoming overripe and losing flavor. All apples held at 36 degrees F showed internal browning, 50 per cent being considered unmarketable. A similar condition as to scald existed in the air sample held at

40 degrees F. On March 9, therefore, both these lots were practically worthless commercially. In contrast, no apples stored in gas showed any browning or scald. The flesh in lots 3 and 4 was prime for eating —crisp and firm. Sample 5, stored in 15 per cent CO_2 seemed scarcely so ripe as samples 3 and 4 (Table II). No carbon-dioxide or alcoholic flavor was noticeable in any fruit.

TABLE II—COMPARATIVE COLOR, FIRMNESS, AND CONDITION OF YELLOW NEWTOWN APPLES MARCH 9, 1934, AFTER BEING STORED FOR 16 WEEKS IN VARIOUS CONCENTRATIONS OF CO_2

Series	Color Index*	Average Firmness (Pounds)	Percentage of Fruit Showing		Flesh	Flavor
			Internal Browning	Scald		
1. Normal air 36 degrees F	2.8	11.9	50, slight 50, moderate	0	Very mellow; partially brown	Rather insipid
2. Normal air 42 degrees F	4.2	12.2	0	50, slight 50, moderate	Mellow	Rather insipid
3. 15 per cent O_2 5 per cent CO_2 42 degrees F	3.1	13.4	0	0	Firm, crisp; noticeably different from above	Good
4. 10 per cent O_2 10 per cent CO_2 42 degrees F	3.0	17.2	0	0	Firm, crisp; noticeably firmer than above	Good, possibly better than above
5. 5 per cent O_2 15 per cent CO_2 42 degrees F	2.4	18.4	0	0	Very firm, slightly woody	Fair to good; scarcely so sweet as samples 3 or 4

*Figures are weighted averages of the percentages of fruit showing different color values.

Fruit in the second series of containers was undisturbed for 25 weeks, or until May 12, 1934. Commercially, few California Newtown apples are stored this late, and the fruit held usually has much better keeping-quality than that used in these experiments. At the previous inspection the samples stored in air had already reached the end of their life. Air-stored samples, however, were carried through until May for comparison (Table III).

The fruit held at 36 degrees F now had a dull, dead appearance, with the flesh predominantly brown. The air sample held at 42 degrees showed no internal browning but was unmarketable because of scald

TABLE III—COMPARATIVE COLOR, FIRMNESS, AND CONDITION OF YELLOW NEWTOWN APPLES MAY 12, 1934, AFTER BEING STORED FOR 25 WEEKS IN VARIOUS CONCENTRATIONS OF CO_2

Series	Color Index*	Average Firmness	Percentage of Fruit Showing		Flesh	Flavor
			Internal Browning	Scald		
1. Normal air 36 degrees F	2.8	8.8	30, moderate 70, bad	70, mostly bad	Soft, spongy, brown	———
2. Normal air 42 degrees F	5.0	7.7	0	100, mostly bad	Overripe; mealy; 40 per cent decay	———
3. 15 per cent O_2 5 per cent CO_2 42 degrees F	3.9	10.5	0	0	Mellow, slightly overripe; 5 per cent decay	Insipid
4. 10 per cent O_2 10 per cent CO_2 42 degrees F	3.0	14.2	0	0	Very firm, moderately crisp and juicy; 5 per cent decay	Slightly insipid; fair
5. 5 per cent O_2 15 per cent CO_2 42 degrees F	3.0	13.4	0	0	Mottled browning in outer flesh; 20 per cent slight decay starting around stems	Slightly insipid; fair

*Figures are weighted averages of the percentages of fruit showing different color values.

and decay. All fruit in the three different containers of CO_2 remained free from scald and internal browning; it was firm, green-colored, and outwardly attractive. Most fruit in 15 per cent CO_2 did, however, show brown, mottled areas (distinct from true internal browning) in the outer portion of the flesh. This condition, not present at the previous inspection, apparently resulted from long holding under this relatively high CO_2 concentration. The fruit stored in a 10 per cent concentration of both CO_2 and O_2 kept in best condition, very firm, predominantly green-colored, with the flesh still moderately crisp and juicy. The flavor had deteriorated somewhat, but, as in the other lots, was not alcoholic. A 5 per cent concentration of CO_2 failed to retard ripening so well. The fruit, though still marketable, was mellow and past its best condition.

Influence of CO_2 Concentration on Sugar and Acid Changes

Usually in the normal ripening of apples, both sucrose and reducing sugars increase, and acid decreases. When the different samples were placed under test, no chemical analyses were anticipated. Samples, however, taken during inspection in March and in May, were analyzed for sugar and acid. The data (Table IV) show no marked or consistent difference in the sugars, either between different storage lots or between the two different inspections. The percentages of acid, however, apparently have some significance and correlation with ripening.

TABLE IV—Sugar and Acid Determinations in Yellow Newtown Apples After Holding the Fruit in Storage for 16 and for 25 Weeks

Series	March 9, 1934			May 12, 1934		
	Reducing Sugar (Per cent)	Total Sugar (Per cent)	Malic Acid (Per cent)	Reducing Sugar (Per cent)	Total Sugar (Per cent)	Malic Acid (Per cent)
1. Normal air 36 degrees F	7.02	9.96	0.32	7.08	9.97	0.20
2. Normal air 42 degrees F	7.69	9.72	0.28	8.08	9.62	0.21
3. 15 per cent O_2 5 per cent CO_2 42 degrees F	7.92	10.00	0.33	8.37	10.01	0.25
4. 10 per cent O_2 10 per cent CO_2 42 degrees F	8.05	9.94	0.33	8.69	10.01	0.28
5. 5 per cent O_2 15 per cent CO_2 42 degrees F	8.07	10.01	0.32	8.07	10.18	0.28

Discussion

The results of this investigation confirm previous tests showing that oiled paper is of slight value in controlling scald in California Yellow Newtown apples and that little internal browning will occur when the fruit is held above 40 degrees F. Under controlled percentages of both CO_2 and O_2, softening and coloring of these apples may apparently be prevented without loss of flavor by storing in CO_2 atmospheres at temperatures that inhibit internal browning.

Acid content was found to decrease as the fruit ripened, but the sugar content showed no definite relation to softening or coloring. In further investigations now in progress, CO_2 content of storage chambers is raised to the desired concentration by respiration and controlled by ventilation.

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Factors Influencing the Cooling of Packages of Fruit

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THE pre-cooling of fruits and vegetables to be sent to distant markets has not been developed as a general commercial practice in the mid-western states. As a rule, growers rely on the refrigerator car to reduce the temperature of the fruit so as to prevent losses due to over-ripening and decay. Earlier marketing studies conducted by the Illinois Experiment Station (1) led to the conclusion that a more complete knowledge of the phenomena occurring in a package of fruit while cooling would be of great value in better understanding the refrigeration problems. It is, also, essential to know how certain external and internal conditions may influence the cooling process.

Methods

Special laboratory equipment was installed to supply a constant air temperature approximating that of the air coming from the bunker of a refrigerator car and in which the air velocity could be varied at will (2). A tub bushel basket with a ventilated liner and a corrugated paper facing pad was the standard package used in these tests. The temperature changes were determined by means of thermocouples suspended in the air spaces between fruits and inserted to the center of fruits. In all, 24 thermocouples were arranged in a cross-section thru the center of the package. Air velocities about the packages were measured by use of the kata-thermometer. The initial temperature readings were taken just before the package was placed into the cooling chamber. Later readings were taken at half-hour intervals during the first eight hours and at intervals as recorded in the tables thereafter. Grimes apples were used in the tests.

Results and Conclusions

From Table I it is evident that relatively large temperature differences are developed between the outer and the inner rows of fruit in a tub bushel basket during the earlier part of the cooling period. After 4 hours in the cooling chamber there is a difference of 12.4 degrees between the outer and third or center rows of fruit. As cooling progresses, the temperature difference becomes smaller, being about 3 degrees when the average fruit temperature is 45 degrees F, which is the temperature considered most practical for transporting fruits in refrigerator cars. The temperature difference between the outer and second row is greater than the difference between the second and third or inner row, thruout the cooling period.

Three sizes of apples, below 2¼ inches, 2½ inches to 2¾ inches, and above 2¾ inches, have been used in filling the basket. The results justify the conclusion that the size of fruit is not an important factor in determining the rate of cooling or in altering the cooling process, as shown in Table I.

The relation of air temperature to fruit temperature in a package of fruit during the cooling process may be of value in helping to understand the phenomena which occurred. In order to secure such information, thermocouples were suspended in air spaces between the

TABLE I—PROGRESS OF COOLING OF APPLES IN LINED TUB BUSHEL BASKET (DEGREES FAHRENHEIT)

Position	Temp. at Start	Temperature at Various Intervals (Hours)									
		2	4	6	8	10	12	20	22	24	26
Air temperature....	36.4	—	—	—	—	—	—	—	—	—	—
Outside of package.	71.1	46.2	45.4	43.6	43.1	42.6	41.7	40.4	39.7	39.6	39.6
First row of fruit...	88.3	78.0	70.0	64.2	59.0	55.4	52.5	47.9	45.1	43.4	43.3
Second row of fruit.	88.8	85.9	79.8	73.2	67.7	62.8	58.6	49.6	47.8	46.8	45.2
Third row of fruit..	88.2	87.1	82.4	76.4	70.6	65.5	61.2	50.9	49.2	48.0	46.5

outer and second rows of fruits and also placed within the fruits. The results from tub bushel baskets under normal conditions show that the air temperature is approximately midway between the fruit temperatures of the two rows (Table II). A similar relationship was found to hold for all packages tested which cooled in about the same time as the tub bushel basket. When packages subjected to similar conditions require a longer time to cool, the results at hand show that the air temperature more nearly approximates the temperature of the inner row of fruit.

A wire-bound slat crate of bushel capacity was tested with the results shown in Table II. This package when exposed to the standard laboratory conditions cooled in less than half the time required for the tub bushel basket. It is interesting to notice that the air temperature between the two rows of fruit in this package is considerably below the temperature of the outside row of fruit. It seems logical to conclude that the relation of the air temperature to fruit temperature within a package is of great importance in determining the rate at which the contents cool. From these studies it appears as though the performance of the refrigerator car may be made more efficient by the use of containers which permit more rapid cooling than those in common use today.

Air velocities about a tub bushel basket below 120 feet per minute do not influence the rate at which the contents cool, provided the temperature of the air coming in contact with the package remains constant (Table III). As the velocity is increased, a point is reached at which cooling progresses more rapidly. A detailed study of conditions within the package shows that with the higher air velocity the air temperature about the fruit is below that in packages exposed to lower velocities. This change is believed to be caused by an increased air circulation within the package exposed to the higher velocity.

TABLE III—EFFECT OF AIR VELOCITY ON RATE OF COOLING (DEGREES FAHRENHEIT)

Air Velocity	Temp. at Start	Temperature at Various Intervals (Hours)										
		2	4	6	8	10	12	20	22	24	26	28
Still air......	73.0	71.5	67.5	64.3	61.1	58.2	55.4	50.1	47.1	46.2	45.2	44.4
88 ft. per min.	77.6	73.2	69.8	64.2	62.0	58.7	56.2	49.2	47.9	46.8	46.5	45.5
116 ft. per min.	75.4	72.3	68.0	63.4	60.8	57.5	55.0	48.5	47.3	46.5	45.6	43.2
156 ft. per min.	75.9	72.4	66.8	60.1	57.2	53.3	51.0	44.1	43.1	42.6	—	—

TABLE II—RELATION OF AIR AND FRUIT TEMPERATURE IN DIFFERENT PACKAGES IN RELATION TO COOLING (DEGREES FAHRENHEIT)

Position	Temp. at Start	Temperature at Various Intervals (Hours)												
		1	2	3	4	5	6	7	8	10	12	20	22	24
Tub bushel basket														
Outside row. .	75.1	71.4	67.9	64.8	62.1	59.6	57.9	56.0	54.8	52.3	50.3	45.0	44.1	43.4
Air temp.	75.0	72.5	69.5	66.8	64.0	62.2	59.7	58.0	56.7	53.6	51.3	45.8	44.9	44.1
Inside row. . .	74.5	74.6	73.3	71.1	68.7	66.2	64.1	61.9	60.2	56.6	53.0	46.9	45.9	45.2
Slat bound crate														
Outside row. .	76.6	68.6	62.4	57.6	53.7	50.6	48.4	46.5	45.3	43.2	41.6	—	—	—
Air temp.	75.9	65.1	59.9	56.0	52.3	49.2	47.4	46.1	44.7	42.6	41.5	—	—	—
Inside row. . .	78.2	73.4	68.3	63.5	59.1	55.4	52.7	50.4	48.4	45.4	43.3	—	—	—

TABLE IV—COOLING OF APPLES BY COLD WELL WATER AND COLD AIR (DEGREES FAHRENHEIT)

Treatments	Temp. at Start	Treatment Period (Minutes)						Removed to Warm Air (Minutes)				
		1	3	5	10	15	20	2	5	10	15	20
Cooling temperature, air.	34.6	—	—	—	—	—	—	—	—	—	—	—
Cooling temperature, water. . . .	51.4	—	—	—	—	—	—	—	—	—	—	—
Air temperature after treatment, air cooled.	—	—	—	—	—	—	—	66.4	—	—	—	—
Air temperature after treatment, water cooled.	—	—	—	—	—	—	—	66.2	—	—	—	—
Fruit temperature, air cooled. . .	73.8	73.8	73.6	73.4	72.0	69.9	67.7	66.2	65.3	64.0	63.4	—
Fruit temperature, water cooled	75.9	75.9	75.7	74.7	—	—	—	72.7	69.9	66.4	64.6	63.8

Many vegetables are pre-cooled preparatory to loading in refrigerator cars by means of cold water. The possibility of reducing the summer temperature of apples by the use of cold well water may be worthy of consideration, especially if the fruit must be washed to remove spray residue.

The results of such a study are shown in Table IV. Here the temperature changes of individual Grimes apples measuring between 2½ and 2¾ inches in diameter were followed. Thermocouples were inserted at various depths into the flesh of the apples. Data are given only for those at the center of the fruit. Temperature readings were taken just before placing the fruit in the water and continued at intervals until 20 minutes after removal from the water. The fruits were placed in water, the temperature of which was between 51 and 52 degrees F (a common well water temperature) for 5 minutes and then removed to air at room temperature. Table IV, also, gives data for individual apples exposed to air at about 34 degrees F for 20 minutes and then removed to warm air. The results show that a 5-minute treatment in cold well water caused a drop of 12 degrees F in the fruit temperature. Cold well water is four times as effective as air at 34 degrees F in reducing the fruit temperature. When warm fruit is packed in a tub bushel basket and exposed to an air temperature of 34 degrees F, as under the condition of the laboratory tests here reported, it requires about 4 hours to secure an equal drop in temperature. When a refrigerator car is loaded with tub bushel baskets of warm fruit in the summer time, it requires about 24 hours to secure a drop of 12 degrees F in the fruit temperature. It is questionable if the full value of the pre-cooling could be retained until the fruit is packed and loaded in the car, but the results of these tests indicate that there are possibilities in such a treatment.

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Freezing Storage in Relation to Microbial Destruction and Retention of Quality in Sweet Cider

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Microbiological Studies

TWENTY-FIVE gallons of fresh cider, mostly from mature Jonathan apples, were placed in the natural state in pint (475 cc) lots in No. 2 lacquered tin cans. The cider was of fair commercial quality, reading 12.4 degrees Balling, with pH of 3.6. Half the cans received, immediately before closure, approximately 0.5 gms solid CO_2 per can. Vacuumization was not used. The samples were at once divided and stored at the following temperatures: –5, 15, 20, and 28 degrees F. At intervals of about 4 weeks, successive sets were withdrawn and thawed for examination. In the microbiological analyses wort agar, pH 4.8, was used as the medium. The survival of yeasts (Saccharomyces) was gauged by placing unbroached cans at 40 and 70 degrees F and watching for evidences of fermentation.

The wort agar count on the fresh cider was approximately 2,000,000 per cc. In the mixed microflora both "true" and "false" yeasts and various fungi, including Penicillium, were represented.

After a month's storage, the uncarbonated cider, excepting the sample held at 28 degrees F, showed a 90 to 96 per cent destruction of microorganisms, while in the carbonated cider, again excepting the 28 degrees F sample, the destruction was 99 per cent or over. As was general throughout the experiment, the greatest "kill" of microforms had occurred at –5 degrees F. At 28 degrees F over half the samples, carbonated and uncarbonated, showed alcoholic fermentation in 2 months, due to growth of cold-tolerant yeast. With the lengthening of the storage period, the phenomenon common to the operation of germicidal agents, namely, a lessening in absolute efficiency on prolonged contact, occurred, and thus at the end of the 10-month observation period, the cider was far from sterile. The lowest counts at this time were yielded by the carbonated samples from –5 and 15 degrees F storage, viz., 30 per cc each. Since this represented some 15,000 microorganisms per container, unbroached cans held at 70 degrees F showed fermentation in about 7 days. When tested at 40 degrees F, however, the cider after 6 months freezing storage remained unfermented for 30 or more days—a fact which indicates that the cold-tolerant yeasts mentioned in connection with 28 degrees F storage were not numerous in the fresh cider and many had been killed by storage at –5, 15, and 20 degrees F.

Quality Studies

For the quality studies, freshly pressed ciders made from mature Jonathan, White Winter Pearmain, Spitzenburg (Esopus), and Winesap apples, grown at Cashmere, Washington, were placed in pint samples in No. 2 plain or lacquered sanitary cans or in 16-ounce

paraffined paper cups having a roll-crimp seal. Sufficient amounts were prepared so that repeated subsequent examinations of the frozen ciders were possible while in the unthawed condition, as well as after thawing in air or in water at 60 to 70 degrees F. Storage of the material took place at the following air temperatures: –5, 15, 20, 28, and 32 degrees F.

The soluble solids and pH readings on the original juice were as follows: Jonathan—12.4 degrees Balling and 3.6; White Winter Pearmain—12.4 degrees Balling and 3.5; Spitzenburg—12.8 degrees Balling and 3.2; Winesap—13.6 degrees Balling and 3.7. The ciders were all of good commercial quality with such differences in sprightliness or flavor as are usually obtained in juices pressed from fruit of these several varieties.

The general quality of the apple ciders was best retained in storage at –5 degrees F, although the differences in flavor and aroma between samples held at 15 degrees and at –5 degrees F, were only slight. At the latter temperature, however, flocculation of the suspended matter in the thawed ciders, apparently favored by the ice formation, was not so complete as in ciders held at 15 and 20 degrees F. At these temperatures the flocs were larger and more aggregated in character, the sludge was more dense and granular in appearance and the supernatant liquid clearer. Redistribution of the sludge material was easily done by shaking the sample. Most observers seemed to prefer to drink the ciders in their naturally turbid condition, although it was not possible to demonstrate any difference in their favor when comparison was made with samples of clarified ciders obtained from the same lots of juice by the use of proper amounts of the commercially manufactured enzyme preparation, "Pectinol E", and frozen at the same temperatures.

Some darkening of the cider packed in paper containers, probably due to oxidation, occurred at all storage temperatures. At –5, 15, and 20 degrees F no flavor deterioration was noted as a result of this oxidation, such differences as occurred being due to storage temperatures. Samples held in any type of container at 28 degrees F eventually fermented, and at 32 degrees F mold growth, in addition, was found on the surface of ciders packed in non-airtight containers.

At temperatures at or above 28 degrees F ciders held in lacquered, sealed cans took on a lighter color as storage went on, often approaching an orange hue. The cause of this could not be determined in the material available.

Evacuation of the air from ciders before packing for freezing in hermetically sealed containers did not significantly influence the quality of the material during or after freezing storage, although as was to be expected where corrosion of unlacquered metal containers occurred, it was less in amount with the vacuumized ciders.

No corrosion took place with different ciders that were stored in plain or lacquered cans at –5 degrees for 2 years. At the higher temperatures, beginning with 15 degrees, increasing amounts of corrosion were observed in plain cans or wherever the lacquer was broken in the enamelled cans, accompanied by the development of a "metallic" taste in the cider.

Ciders, carbonated as described for the microbiological studies or by subjecting the liquid to evacuation and releasing the vacuum in an atmosphere of CO_2, all retained the original flavor well for 2 years when frozen at –5 and 15 degrees. The carbonated taste was lost soon after the containers of thawed material were opened and left at room temperature.

Conclusions

A rapid decrease, as much as 90 per cent or more, in numbers of viable microörganisms occurred in sweet cider frozen in the temperature range –5 to 20 degrees F for a month. Thereafter, microorganisms were destroyed at a progressively slower rate. The addition of CO_2 was found to accelerate slightly the death rate. Cider did not become sterile from prolonged freezing, though when thawed in unopened containers, its "keeping" qualities showed improvement. Except for short periods, storage of cider at 28 degrees F did not suppress microbial growth.

Freezing preservation of cider was satisfactorily done at –5 degrees F in airtight or non-airtight containers. At this temperature, the original beverage quality of the cider—color, flavor and odor—was best retained, and corrosive action on metal containers seemed to be permanently suppressed.

Peach Storage With Special Reference to Breakdown

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IT has been reported (1) that the storage of peaches for any extended time is not practical. After prolonged storage at low temperatures the peaches either fail to develop good dessert quality when ripened or develop breakdown and decay in storage or during the ripening process at higher temperatures. Previous investigations (1930, 1931, and 1932) indicated the most favorable storage conditions for peaches was 31 to 32 degrees F with high humidity. At these temperatures the fruit softened very slowly and could be held for 3 to 5 weeks, then transferred to higher temperatures and ripened.

The poorest storage conditions were encountered when peaches were held at 40 degrees F. Such fruit failed to ripen normally in storage and developed breakdown at this temperature or in the ripening room (70 degrees) after transfer.

Breakdown has commonly gone unobserved probably because observations have been based on the appearance of the fruit while at low temperatures. Breakdown was not observed first at low temperatures. It usually developed during ripening at 70 degrees F after 2 weeks' storage at 40 degrees. After the third week of storage, breakdown nearly always developed in the ripening room in lots stored at 40 degrees, prior to transfer. Quality was based on the condition of the ripe fruit, not on its appearance in cold storage; therefore our experimental data deals primarily with fruit behavior during ripening at 70 degrees.

Description of Breakdown

It has been shown previously (1) that peach breakdown is of a physiological nature. The first stages of breakdown have been described as a water-soaked appearance around the stone. In later stages the water-soaked areas became larger and turned brown and the entire flesh became brown and mealy. Subsequent work has given additional information, indicating that mealiness may be the first indication with such varieties as Hiley, Slappey, and Late Crawford. In later stages the tissue around the stone becomes brown with a typical water-soaked appearance. Even during the early stages, the quality is greatly impaired. The fruit is usually flavorless, dry, and mealy.

Materials and Methods

Since the writers had worked largely with four varieties of peaches, namely, Carman, Belle, Elberta, and J. H. Hale, it was not known how universal breakdown might be. In 1933 it was decided to test all varieties available and to ascertain which varieties were least susceptible to breakdown and decay.

Carman, New Jersey 66, New Jersey 12722, Hiley, Slappey, Champion, Early Crawford, and Elberta were obtained from the variety orchard at Arlington Farm, Virginia; and J. H. Hale, Belle, Augbert (Roberta), and Late Crawford from the variety orchard of the University of Maryland, College Park, Maryland. All the fruit was

selected for uniform maturity and picked at a color stage corresponding to shipping ripe condition. At this stage of maturity the firmness of the early varieties averaged 8 to 12 pounds and of the late varieties from 12 to 15 pounds depending on the variety. The firmness was determined with a pressure tester using a 5/16-inch diameter plunger with a penetration of 5/16 of an inch.

The peaches were placed in bushel baskets and stored at 32 and 40 degrees F. At weekly intervals, samples of not less than half a bushel were transferred to 70 degrees for ripening and observation. When full ripe the amount of breakdown and decay and the dessert quality was determined. Additional samples were frozen (using a 50 per cent sugar solution) to aid further in the evaluation of dessert quality. After the frozen samples had been held about 6 months at 17 degrees they were removed to 60 degrees for thawing and quality evaluation. This additional means (frozen samples) of checking quality was very satisfactory and the notes compare closely with the records taken on the fresh samples.

Discussion of Results

The storage of peaches at 32 degrees F does not prevent the development of breakdown. In all varieties tested it does postpone the time of its development. (See Table I.)

No breakdown developed in storage at 32 degrees F or during ripening at 70 degrees in the varieties New Jersey 66, New Jersey 12722, and Slappey. Early Crawford and Late Crawford were successfully held 5 weeks at 32 degrees and ripened at 70 degrees with 5 and 9 per cent breakdown. Breakdown developed in Elberta, J. H. Hale, Belle and Augbert (Roberta) after 4 weeks' storage at 32 degrees, and in Hiley and Champion when ripened after 3 weeks' storage at 32 degrees.

On the other hand all varieties tested developed breakdown when stored at 40 degrees F usually after 2 weeks' storage. Breakdown frequently developed during ripening at 70 degrees, but was generally found in the storage lots prior to transfer.

Peaches showing highest percentages of breakdown after 2 to 3 weeks' storage at 40 degrees F were New Jersey 12722, New Jersey 66, and Carman; Late Crawford, Belle, Slappey, J. H. Hale, and Early Crawford were intermediate; Elberta, Hiley, and Augbert (Roberta) were least susceptible.

The highest percentages of decay (primarily brown-rot) developed in fruit ripened at 70 degrees F after storage at 40 degrees. New Jersey 66, a very acid peach, Slappey and Belle were least susceptible to brown-rot.

Conclusions

Although peaches cannot be held in storage many weeks, they are often stored to extend the marketing period and are often shipped under refrigeration considerable distances to marketing centers.

Storage of peaches at 40 degrees F or even 36 degrees has proven unsatisfactory either because of the development of breakdown at these temperatures or because of the high percentages of decay and

TABLE I—The Effect of Length of Storage at 32 and 40 Degrees F on the Condition of Peaches Ripened at 70 Degrees F.

Storage Temp. (Degrees F)	Weeks in Storage	Days at 70 Degrees F	Sound (Per cent)	Decay (Per cent)	Break down (Per cent)	Quality: Fresh Sample	Quality: Frozen Sample
				New Jersey 66			
—	–	6	98	2	0	Very good	Very good—attractive
40	2	3	97	3	0	Fair to good	Fair
40	3	2	57	0	43	Poor—dry, mealy	Poor
40	4	2	0	10	90	Very poor—Breakdown	Very poor
32	2	5	100	0	0	Very good—sour, juicy	Good
32	3	3	100	0	0	Good—juicy	Good
32	5	4	100	0	0	Fair, juicy, slightly mealy	Poor
				J. H. Hale			
—	–	5	37	63	0	Good	Very good
40	1	3	61	39	0	Good, juicy, fairly sweet	Fair to good
40	2	2	54	46	0	Fair to good	Fair
40	3	1	43	20	37	Fair, lacks flavor	Fair to poor
40	4	1	4	29	67	Poor, mealy	Poor
40	5	2	16	23	61	Very poor, mealy	Very poor
32	1	3	94	6	0	Good, juicy, fairly sweet	Fair to good
32	2	3	88	12	0	Very good, very juicy	Good
32	3	2	91	9	0	Fair, slightly sour	Fair to good
32	4	3	74	16	10	Good, juicy	Fair to poor
32	5	2	45	24	31	Fair to poor, tough	Poor
32	7	2	0	83	17	Poor, slightly sour	Poor
				Late Crawford			
—	–	6	79	21	0	Good to fair, slightly sour	Good
40	1	4	78	22	0	Good, juicy, slightly sour	Fair
40	2	2	75	20	5	Fair, slightly mealy	Fair to poor
40	3	2	53	47	0	Poor, mealy	Poor
40	4	1	28	18	54	Poor, dry, mealy	Poor
40	5	1	12	12	76	Very poor, mealy	Very poor
32	1	4	76	24	0	Very good, sweet and juicy	Good to fair
32	2	4	93	7	0	Good	Good
32	3	3	84	16	0	Very good	Fair
32	4	2	90	10	0	Fair, slightly sour	Poor to fair
32	5	4	66	25	9	Fair, slightly sour	Poor

breakdown which developed after the fruit was transferred to 70 degrees for ripening.

Just how long peaches should be held in storage at 31 to 32 degrees F depends on their resistance to decay and breakdown, and on the ability of the fruit to produce good or fair dessert quality when ripened. Using these criteria, the maximum storage life of certain varieties are listed: New Jersey 66 and New Jersey 12722, 4 to 5 weeks; Late Crawford and J. H. Hale, 4 weeks; Slappey, Augbert (Roberta), and Elberta, 3 to 4 weeks; Belle, Champion, Hiley, and Carman, 2 to 3 weeks.

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Certain Physiological Effects of Carbon Dioxide Treatments of Plums

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THE use of short period treatments ot carbon dioxide at relatively high concentrations as a substitute for precooling of fruits and vegetables has been investigated with rather encouraging results by Brooks, et al. (1).

Carbon dioxide treatments of this nature would be of particular value for the shipment of fresh fruits of Italian Prune from the irrigated districts of the Pacific coast region. A large percentage of Italian Prune fruit from these districts is packed either on the ranch or in warehouses where no precooling facilities are available. The usual practice after packing is to load this warm fruit into iced cars for immediate shipment. The Italian Prune harvest in this region generally occurs during August which is the warmest period of the season. It is only natural that a certain amount of softening and mold growth takes places during the period in which this warm fruit is being cooled in the car.

Materials and Methods

During the season of 1932 the writer began a series of experiments to determine the effect of short exposures of carbon dioxide at various concentrations not only upon the keeping quality, but also upon certain chemical changes in the Italian Prune. Due to the short storage life of Italian Prune, analyses were necessarily made at frequent intervals. This fact rather limited the amount of investigational work to be attempted in any one season.

The fruits for these experiments were harvested from a chosen block of trees in a well cared for orchard of the Yakima Valley. No attempt was made to use fruit of different maturities. Each season the fruit was harvested at what was considered optimum commercial maturity, namely at about 9 pounds pressure by the U. S. D. A. pressure tester. After harvest the fruit was immediately placed in gas tight chambers at the temperature desired. The gas treatments were manipulated by means of a continuous flow of carbon dioxide and air thru the fruit containers, the flow being regulated by means of flow meters. Carbon dioxide analyses of the outcoming gas were made at frequent intervals during the treatment period. No attempt was made to control the oxygen concentration, but as a definite amount of air was being passed into the chambers the oxygen content was presumed to be in direct proportion to the amount of air. For instance, if 40 per cent carbon dioxide and 60 per cent air were being passed thru the chamber, the oxygen content of that particular chamber would be approximately 12.6 per cent. After the 48-hour gas treatment the fruit was removed from the treatment chambers and placed at the desired storage temperature.

At intervals during the storage period samples were removed for analysis of sugar, titratable acid, ethyl alcohol, and acetaldehyde. The

respiration in terms of carbon dioxide was measured in certain treated and untreated lots. The effect of the various gas treatments on the composition and physiology of the fruit will be discussed.

Ethyl alcohol and acetaldehyde:—Ethyl alcohol was determined by a slight modification of the method used by Thomas (2) and is reported as milligrams per kilogram of fresh tissue. The above mentioned author, in a study of artificial atmospheres with apples, has differentiated between the effect of carbon dioxide atmospheres containing less than 5 per cent oxygen and those containing more than 5 per cent oxygen. Results of the former environment he has chosen to call anaerobic zymasis and of the latter CO_2 zymasis. As all treatments presented here contained more than 5 per cent oxygen the effects should probably be classed as CO_2 zymasis. Italian Prunes, however, seem to present an entirely different physiological picture than do apples. Thomas (2) reports no accumulation of ethyl alcohol or acetaldehyde in apples stored in normal air, whereas the writer found a distinct accumulation of ethyl alcohol and some increase in acetaldehyde in untreated prunes after several weeks of storage. Fig. 1 shows that the prunes contained 73 milligrams of ethyl alcohol per

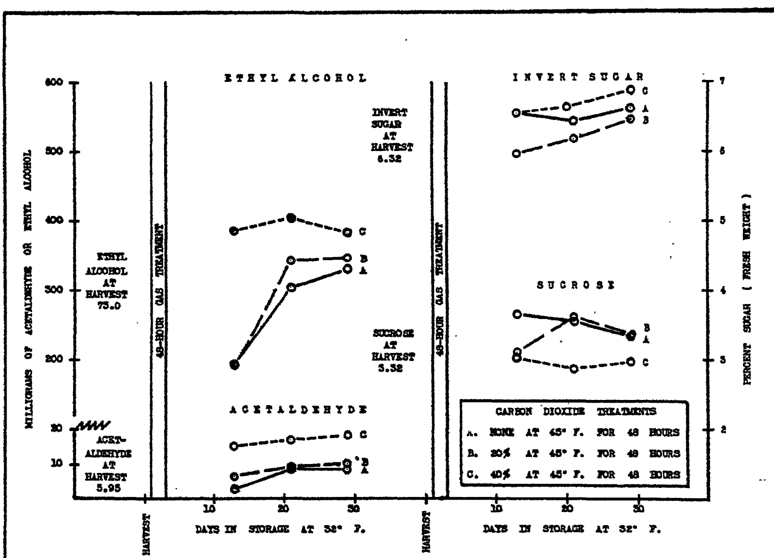

FIG. 1. Effects of short treatments of CO_2 gas on fruits of Italian Prune. 1932.

kilogram of fresh tissue at time of harvest. Four days after the carbon dioxide treatment the untreated fruit and that treated with 20 per cent CO_2 showed about 190 milligrams of alcohol, while the fruit treated with 40 per cent CO_2 increased to nearly 400 milligrams. Further cold storage tended to equalize the ethyl alcohol content. Samples removed after 28 days cold storage and ripened for several days (not shown

on chart) all showed an increased ethyl alcohol content, but indicated no significant difference between the untreated, and those receiving 20 to 40 per cent CO_2.

Experiments conducted in 1933 with none, 20 and 40 per cent CO_2 at 32 degrees F and similar concentrations at 65 degrees showed no significant increase in ethyl alcohol content of any of the lots treated at 32 degrees, but showed a large increase in ethyl alcohol in the lot treated with 40 per cent CO_2 at 65 degrees. It would appear from this fact that the temperature at which the gas treatment is given might be a distinct factor.

In 1934 the gas treatments were again continued at 45 degrees F. Treatments of none, 20, 40, and 60 per cent CO_2 were given for 48 hours. The results were shown in Fig. 2. In this case no appreciable

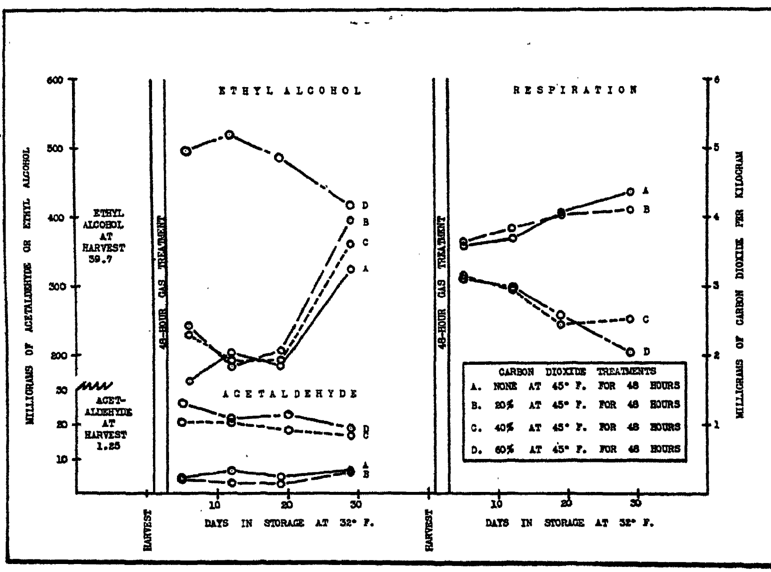

FIG. 2. Effects of short treatment of CO_2 gas on fruits of Italian Prune. 1934.

increase in ethyl alcohol content was observed except with the lot treated with 60 per cent CO_2. As previously indicated there was a tendency for all lots to approach equality in ethyl alcohol content as the storage period increased.

Acetaldehyde was determined by the method of Thomas (2) and is reported as milligrams of acetaldehyde per kilogram of fresh tissue. In general (as the charts show) the acetaldehyde content is in direct relationship to the amount of ethyl alcohol. Those treatments which caused initial rise in the ethyl alcohol content also caused an increase in the acetaldehyde. The only exception to this is recorded in Fig. 2. In this case the acetaldehyde content was materially increased by the 40 per cent CO_2 treatment; whereas the ethyl alcohol content was not affected.

Sugars:—Samples for sugar analysis were taken at intervals during the 1932 and 1934 investigations. These were prepared by preservation of the fresh, ground tissue in boiling alcohol according to the method described by Culpepper and Caldwell (5). Unfortunately, analyses of the 1934 samples have not been made at this time, so only the 1932 results can be reported. Sucrose was determined by difference in copper reducing power before and after acid inversion, while invert sugar was measured by direct copper reduction using the Quisumbing and Thomas (3) reduction procedure and the Shaffer and Hartman (4) titration technique.

The Italian Prune being a non-starchy fruit shows no increase in total sugar after harvest. Therefore, the only concern of this investigation was to determine the relative proportion of sucrose to reducing sugar at harvest and at intervals after treatment. Miller and Brooks (6) have reported that concentrations of about 45 per cent CO_2 for 2 days produced no effect upon the carbohydrate content of cherries and peaches. Their results apparently refer only to that stage immediately after the gas treatment and not to that after subsequent storage periods. Fig. 1 shows the sucrose and reducing sugar content at harvest and at intervals during storage. There appears to be a higher reducing sugar content and lower sucrose content in the fruit treated with 40 per cent CO_2 than in that treated with 20 per cent or no CO_2. It is questionable, however, on the basis of one year's results whether these differences are significant.

Respiration:—Carbon dioxide output of duplicate lots of fruit from untreated, 20, 40, and 60 per cent CO_2 was determined by the Truog tower absorption method using KOH solution as the absorbent.

It is generally assumed that the respiration of fruit is materially decreased while under atmospheres containing abnormally high concentrations of CO_2. It is, however, largely a matter of conjecture as to how much, if any, the respiration of the fruit is subsequently affected after removal from artificial atmospheres into normal air. Curves shown in Fig. 2 indicate that the respiration of Italian Prunes treated with 40 and 60 per cent CO_2 was very materially affected as compared with the respiration of untreated lots and those treated with only 20 per cent CO_2. The carbon dioxide output of the check and 20 per cent CO_2 treated fruit shows an upward trend with continued storage, while the prunes treated with 40 and 60 per cent CO_2 respectively show a lower output immediately after treatment and the output subsequently decreases.

Gerhardt and Ezell (7) have reported a rapid loss of CO_2 from pears and apples after removal of the fruit from high CO_2 concentrations to normal air. Assuming that the response of Italian Prunes is similar to that of the above mentioned fruits, the reduction in the respiration rate after CO_2 treatment was probably due to toxic products formed while the fruit was under CO_2 treatment rather than to high CO_2 concentrations in the tissue after treatment. This belief is substantiated by the fact that the respiration of the lot treated with 20 per cent CO_2 was unaffected while the respiration of the lots treated with 40 and 60 per cent CO_2 was materially reduced. A study of Fig. 2 will reveal that the acetaldehyde content of the lot treated with

20 per cent CO_2 was unaffected, as compared with the check, while the acetaldehyde content of the lots treated with 40 and 60 per cent CO_2 was materially increased by the gas treatment. This would indicate a relationship between acetaldehyde formation and reduced respiration. Fruit from each of these lots was withdrawn from cold storage at the end of 30 days and the carbon dioxide output was determined at 65 degrees F. The untreated lots and those treated with 20 per cent CO_2 still showed a somewhat larger CO_2 output than the lots treated with 40 and 60 per cent CO_2, but the difference was not great.

Keeping quality:—All CO_2 treated lots showed distinctly less softening and less decay after several weeks cold storage than the check lots. No attempt was made to determine the firmness of the different lots by mechanical means, but careful examination, at intervals during storage, failed to show any difference in firmness between the lots treated with 20 40, and 60 per cent CO_2. Apparently the difference in firmness between the check and treated lots was due to the more rapid softening of the check lot during the 48-hour period at 45 degrees. After 3 weeks cold storage and subsequent ripening at 65 degrees F for several days, all lots contained a high percentage of fruit showing a characteristic browning about the pit which apparently is associated with normal deterioration in storage.

Dessert quality:—No off flavors could be detected in any of the lots during the first 2 weeks of storage. Even the fruit which showed relatively high alcohol and acetaldehyde concentrations had no detectable fermented flavor. After the third week of cold storage all lots, when ripened, contained fruits having a fermented flavor. This was invariably associated with the flesh browning previously mentioned.

Summary

Fruits of Italian Prune were exposed to different concentrations of carbon dioxide for relatively short periods.

Concentrations of 40 per cent CO_2 or over usually caused a marked increase in ethyl alcohol and in acetaldehyde content. The ethyl alcohol content of the treated and untreated lots tended to attain a similar magnitude with continued air storage at 32 degrees F.

There appeared to be an accumulation of ethyl alcohol in untreated prunes during extended storage.

Carbon dioxide treatments of 40 per cent or more materially affected the rate of carbon dioxide output of the fruit subsequent to the treatment. In these lots acetaldehyde accumulated in relatively large amounts and normal respiration was markedly depressed.

All of the lots treated with CO_2 were firmer and showed less mold development after storage than the untreated lots. Flesh browning around the pit was not significantly affected by the CO_2 treatments.

No relationship could be determined between CO_2 treatments and subsequent flavor of the fruit.

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How Poisonous Is Spray Residue?

By T. J. TALBERT, *University of Missouri, Columbia, Mo.*

THE spraying of fruits offers a perplexing problem because poisons must be used to prevent insects from destroying food products. The sprays and dusts must, also, to be effective contain adhesive properties. As a result the spray residues are often difficult to remove properly. The lead which is combined with arsenic is an adhesive substance and it is also a poison.

Since the producers of fruit crops must use poisons or insecticides in order to raise for home consumption and for sale on the general markets the foods required, is it not obvious that growers, federal and state inspectors, and others should be reasonable, just and cooperative in the establishment of limits or tolerances which are safe and which can be met by the producers without great difficulty? If this is not done, a barrier, which cannot be justified, is placed against the fruit industry that discourages producers, inhibits progress and delays recovery.

Upon the recommendations of toxicologists, tolerances for both arsenic and lead have been promulgated and established by the U. S. Department of Agriculture, Food and Drug Department. At the present time this tolerance for arsenic is 0.01 grain of arsenic trioxide per pound of fruit. For lead it is 0.019 grain per pound of fruit during the season of 1934.

LACK OF EVIDENCE OF HARMFUL EFFECT

It is the consensus of opinion among apple growers that such a procedure is not warranted in view of the fact that evidence is lacking to show that the residue on sprayed apples does produce harmful effects. Only opinions and guesses are presented. Wild stories regarding the ill effects produced from eating sprayed fruits have been circulated. When such stories have been properly investigated, they have been found to be false. The ill effects produced have usually been due to over-eating or eating green and immature fruits.

PRESENT LIMITS—LOWER OR HIGHER?

The so-called tolerances for both arsenic and lead have apparently been arrived at more or less arbitrarily; that is, without adequate scientific evidence upon the toxicity of spray residue. In other words, the tolerances, from the information we have, might have been placed just as properly somewhat higher or lower. No one can offer authentic proof to the effect that the consumer of apples would have been affected differently.

Why such a limit was chosen is unknown to Dr. C. N. Myers, of New York City, and his associates (5), known widely because of their interest in present day public health problems. They state that, "as a result of several thousand cases, it has been observed by us that a little arsenic is just as bad as a little more."

ARSENIC IN SEA FOODS

The assumption that even the presence of arsenic condemns or convicts a particular food is wrong, unfair, and unjust. Nearly all of

our sea foods contain comparatively large quantities of arsenic. In fact, in most cases it amounts to more than that found in the spray residue on fruits. The oyster contains .01 to .0165 grain of arsenic trioxide per pound. The Missouri Agricultural Experiment Station has also found that codliver oil, which is given freely to children contains 0.027 to 0.054 grain of arsenic trioxide per pound.

Holmes and Remington state: "In view of the widespread use of codliver oil, particularly by babies and young children, and the firm scientific foundation on which it rests, it seemed of interest to determine the arsenic content of codliver oil. Sadolin examined two samples of cod, finding, respectively, 0.4 and 0.8 p. p. m. (0.0027 to 0.005 grain per pound) of arsenic in the flesh, 0.7 and 3.2 p. p. m. (0.0048 to 0.0022 grain per pound) in the liver, and 3.0 and 4.5 p. p. m. 0.0207 to 0.0305 grain per pound in the liver oil. Fat extracted from muscular tissue of eels and herrings contained most of the arsenic of the tissue; hence Sadolin concluded that the arsenic of fish is in fat-soluble form. Fellenberg on the other hand found about 20 times as much arsenic in dried codfish meal as in codliver oil".

According to T. Swann Harding (2), the following sea foods contain arsenic trioxide in the amounts listed:

Lobster	0.0160 to 0.126	grain per pound
Codfish	0.0140 to 0.0380	grain per pound
Haddock	0.392	grain per pound
Clams	0.0104 to 0.0180	grain per pound
Shrimp	0.0170 to 0.0770	grain per pound
Sardines	0.0105 to 0.0200	grain per pound
Prawns	0.125	grain per pound
Crabs	0.0140 to 0.0770	grain per pound

Mr. Harding further states that, "of 1169 samples of common foods of all classes, 11 per cent contained arsenic trioxide in excess of 0.01 grain per pound", the world tolerance for apples.

Recent information dealing with the "Toxicity of Naturally Occurring Arsenic in Foods" show that there is no direct experimental evidence available at the present time which proves that the natural arsenic in marine foods, if consumed regularly over long periods of time, will or will not produce harmful effects (1).

This work also shows that there is a difference in the metabolism of the arsenic as it occurs in shrimp as compared to inorganic arsenic and that only a small percentage of the arsenic contained in shrimp is absorbed and stored in the animal body.

It is significant to note, however, in these experiments, that there was no retardation of growth in any of the arsenic-fed animals nor any observable differences in their physical vigor or appearance. Furthermore, a histological study showed that there was no evidence of injury to the spleen, liver, or kidney due to the feeding of organic or inorganic arsenic.

Some Experimental Results

O'Kane, Hadley, and Osgood (6), of the New Hampshire Agricultural Experiment Station conducted experiments from 1912 to 1916 in order to determine the possibilities of poisoning from residues

of arsenate of lead. The authors state: "So far as our experiments with Guinea pigs may be relied upon, the results indicate that five or even ten times the maximum per apple found in the analyses could not be expected to constitute a dangerous dose for a human being. It is quite true that a Guinea pig may be less susceptible to the poison than a human being, but the weight of a Guinea pig is 1/100 of the weight of an adult human being. Even if the Guinea pig is less susceptible, we should not expect any such ratio as 1/100. Moreover, since the Guinea pig can ingest daily, without serious poisoning, amounts of arsenate of lead equal to the average maximum found on six apples, we should not expect to get serious or fatal results to follow the daily ingestion of an equal amount by an adult person."

From the work of Talbert and Tayloe (7), of the Missouri Agricultural Experiment Station, on feeding spray chemicals to rats, detrimental results were noticeable only when rats were fed large dosages over long periods of time. At no time was acute toxic action noticeable. These authors state:

"Arsenic salts in quantities ranging from the equivalent of four times to two hundred times the official world tolerance may promote activity and growth in the original stock for the first twenty-three to twenty-five weeks.

"Our experience indicates that the arsenicals in fruit sprays have, in fact, acute stimulating effects, and injurious effects are brought on only when feeding is regular and prolonged, as shown in the feeding periods ranging from 378 to 497 days.

"If it may be assumed that the spray chemicals have an effect upon man similar to that which they have upon albino rats, it is the opinion of the authors that there is little likelihood of a human consuming as spray residue on apples, sprayed and handled in the usual manner, enough arsenic or lead either at one time or over an extended period to be injurious."

The custom of eating arsenic is common even at the present time in Styria, a province of Austria (3). Gray is the largest city in the province. In the treatment of iron ores arsenic makes its appearance, perhaps the origin and history of arsenic eating is related to the iron industry. As_2O_3 is the form commonly eaten but many prefer yellow arsenic which is partly As_2S_3. Many yellow arsenic preparations which are eaten contain 75 to 92 per cent As_2O_3.

Lead in Drinking Water

The following table shows the lead content of drinking water from various sources in and near Columbia, Missouri as determined by the A. O. A. C. method of analysis (Method IV—Tentative) on 4 liter samples:

TABLE I—Lead Content of Water

Source of Water	Mgs per Liter	Grains per Pound
House cistern	.040	.00028
Cistern with lead painted drain	.130	.00091
Laboratory faucet	.1000	.00070
Distilled water from faucet	.015	.00010
Water from downtown cafe	.100	.00070

Since it is often recommended that each person should drink at least 10 glasses of water per day, it is interesting to note the amount of lead obtained per day from water and from one apple having the maximum lead residue permitted by the lead tolerance of .019 grain per pound of fruit. An average apple weighs about ¼ to ½ pound and 1 glass or half-pint of water weighs about ½ pound.

TABLE II—LEAD FROM 10 GLASSES OF WATER COMPARED WITH LEAD ON ONE APPLE AT TOLERANCE OF .019 GRAIN PER POUND OF FRUIT

Source of Water	Grains Lead in 5 Pounds H_2O	Weight of One Apple	Grains of Lead
Cistern with painted drain.........	.0045	.25 lbs.	.0048
Cafe faucet.....................	.0035	.33 lbs.	.0063
Laboratory faucet...............	.0035	.5 lbs.	.0095

Thus it seems that one would obtain as much lead per day from drinking 10 glasses of water as from eating one apple. Moreover, since water is consumed much more regularly throughout the year than apples the amount of lead received from water is likely to be greater. Furthermore, a large percentage of apple consumers remove the peeling, in which case no lead is received. But, if we assume that the apples are eaten with the peeling, since 35 to 40 per cent of the lead is found in the calyx and stem ends, only about 60 to 65 per cent of the lead on the apple would be consumed.

Assuming that the average person eats about one-fourth of an apple per day throughout the entire year, which is more nearly correct than an apple a day, and that this apple (average weight) weighs ½ pound, then he receives only ⅛ pound of apple per day. If this fruit has the maximum tolerance limit of .019 grains of lead per pound of fruit then the lead obtained from this quantity of apples per day would be $\frac{.019}{8} = .0023$ grains. When this is compared with the amount of lead found in drinking water, .0035 – .0045 grains of lead in 10 glasses of water, it will be observed that the amount of lead is approximately twice that found on one-fourth of an apple.

There is still another comparison that can be obtained by using data from the *1932 Yearbook of the United States Department of Agriculture* which gives the total apple production for the United States in 1930 as *155,982,000 bushels.* This would be 62.4 pounds per person per year or .17 pounds per person per day of apples. If this fruit had the tolerance limit of lead as residue then the amount of lead obtained from .17 pounds would be only .0032 grains per day which is still about the same amount that would be obtained from average drinking water.

Of course we eat other fruits containing lead residue such as pears, peaches, plums, cherries, apricots, etc., which would increase the total amount of fruit consumed. However, it must be considered that only a fraction of this fruit is consumed in the raw state and much is sold or used in the canned form, usually free from peelings or epidermis

containing the lead residue. Furthermore, if the upper limit of lead tolerance on fruit consumed is .019 grains per pound it is reasonable to assume that some of the fruit will contain less than this amount and thus reduce the average.

According to some excitable persons the eating of sprayed apples causes a dangerous accumulation of lead in the human system. It should be clear from these analyses of drinking water that if lead is accumulative, there is likely to be as great or a greater accumulation occurring from the use of water in various ways.

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Additional Experiments on Spray Residue Removal[1]

By F. L. OVERLEY and E. L. OVERHOLSER,[2] *State College of Washington, Pullman, Wash.*

THE continued lowering of the tolerance for lead on apples and pears is to a considerable extent responsible for many varied spray programs used by the apple growers of the Pacific Northwest in their efforts to control insect infestation and to minimize the problem of spray residue removal. Studies were made of the 1933 season washing records of 410 growers in the Wenatchee district. There were 139 different combinations of spray materials used by these growers. While the spray program used during the 1934 season did not vary so widely, nevertheless, there were still many different programs employed. Special efforts are being made to recommend the adoption of a fewer number of standard spray programs that will give satisfactory codling moth control and that will permit the use of a more standard program of removal of residue after harvest.

Standard spray schedules:—Spray residue removal studies were made employing three lots of apples, each of which had been sprayed with one of three very satisfactory codling moth control spray schedules. Samples of each of the three lots were washed through some of the best of the commercial washing machines in use in the Northwest. The spray schedules are in Table I.

TABLE I—THE CODLING MOTH SPRAY SCHEDULES GIVEN TREES FROM WHICH WERE HARVESTED APPLES FOR WASHING IN COMMERCIAL MACHINES

Legend	Spray Schedules
1 D	Lead arsenate 3 pounds to 100 gallons plus ¼ pound of soap used as spreader for calyx and seven cover sprays.
2 S	Lead arsenate 2 pounds to 100 gallons for calyx followed by six covers of lead arsenate of 2 pounds to 100 gallons plus 2 quarts of kerosene emulsified with soap.
3 E	Lead arsenate 3 pounds to 100 gallons in calyx spray followed by lead arsenate, 3 pounds to 100 gallons with mineral oil ¾ gallon for two cover sprays, and then lead arsenate 3 pounds to 100 gallons plus 1 pint fish oil for four cover sprays. Both types of oil were emulsified with oleic acid and sodium silicate.

Winesap apples of sizes 163 to 175 specimens per box were selected from plots receiving these spray schedules. The specimens were picked within 3 days from each plot and handled in a comparable manner.

Washing machines:—Samples of the three lots of apples were

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[2]The authors wish to acknowledge aid from the Division of Chemistry of the Agricultural Experiment Station of the State College of Washington, from the Wenatchee Valley Traffic Association in analyses for lead and arsenic, and from the Division of Entomology of the Agricultural Experiment Station and R. A. Dull, M. G. Sorenson, and Mr. Etzkorn, fruit growers in the Wenatchee district, for the sprayed lots of apples used in the experiments.

washed in 19 different commercial washing machines operated in the larger grower and central packing houses of Wenatchee and Yakima, Washington, and of Hood River, Oregon. The temperatures and concentrations of the solutions in each machine were carefully determined at the time the fruit was washed.

The washing equipment was divided into groups according to type of equipment. The solutions used were generally the same, hydrochloric acid (HCl) and sodium silicate (SS). There was some variation in concentration of solutions and temperatures and for this reason a direct comparison of the different washing machines can not be

TABLE II—LEAD RESIDUE REMOVAL FROM APPLES RECEIVING THE THREE SPRAY SCHEDULES AFTER WASHING WITH TANDEM COMMERCIAL AND EXPERIMENTAL WASHING MACHINES

Group	Type of Washing Machine and Washing Program	Spray Schedule Legend and Spray Residue (Pb)		
		1 D	2 S	3 E
O	Unwashed fruit (grains Pb per pound)	.457	.310	.364
A	Dipping tank step over type of washing machine			
	(a) SS 108 pounds per 100 gallons, + (6 pounds Detergent E) 116 degrees F, 60 seconds immersion by HCl 1.6 per cent, + 4 pounds Det. E per 100 gallons 96 degrees F, 35 seconds immersion	.017	.013	.022
	(b) HCl 1.3 per cent, 90 degrees F, 40 seconds immersion by HCl 1.3 per cent, 108 degrees F, 20 seconds immersion	.038	.030	.024
B	Combination paddle dipping flotation tank SS 80 pounds per 100 gallons, 114 degrees F, 30 seconds immersion by HCl 1.6 per cent + 3 pounds Vatsol per 100 gallons, 110 degrees F, 120 seconds immersion	.015	.013	.010
C	Step over flood washing machine			
	(a) SS 109 pounds per 100 gallons, 110 degrees F, 32 seconds immersion by HCl 1.78 per cent + 1 per cent 60 visc. M. O., 103 degrees F, 17 seconds immersion	.011	.009	.009
	(b) CHl 1 75 per cent + 1 per cent M. O.60 visc., 112 degrees F, 32 seconds immersion by HCl 1.8 per cent, + 1 per cent 60 visc. M. O., 90 degrees F, 17 seconds immersion	.012	.009	.009
D	Combination paddle dipping tank and bar conveyor overhead spray type of washing machine HCl 1.17 per cent + 1 per cent Vatsol, 85 degrees F, 70 seconds immersion by HCl 1.6 per cent + 1 per cent NaCl + 1 per cent M. O., 104 degrees F, 28 seconds immersion	.007	.009	.009
E	Underbrush overhead flood washing machine			
	[1](a) SS 103 pounds per 100 gallons + soap, 122 degrees F, 15 seconds immersion by HCl 1.6 per cent, + 3 per cent M. O. 92 degrees F, 45 seconds immersion	.005	.004	.004
	[1](b) HCl 1.3 per cent, 102 degrees F, 30 seconds immersion by SS 85 pounds per 100 gallons + soap 110 degrees F, 15 seconds immersion	.004	.003	.003

[1]The State College of Washington Experimental Fruit Washer. Washington Agricultural Experiment Station Bul. 285. 1933.

TABLE III—LEAD RESIDUE REMOVAL FROM APPLES RECEIVING THE THREE SPRAY SCHEDULES AFTER WASHING WITH SINGLE WASHING MACHINES

Group	Type of Washing Machine and Washing Program	Spray Schedule Legend and Spray Residue (Pb)		
		1 D	2 S	3 E
O	Unwashed fruit (grains Pb per pound)	.457	.310	.364
H	Underbrush overhead flood washing machine			
	SS 90 pounds per 100 gallons, 112 degrees F, 30 seconds immersion	.017	.019	.013
	HCl 1.1 per cent + 1 per cent kerosene, 105 degrees F, 25 seconds immersion	.030	.027	.049
	HCl 1.6 per cent, 110 degrees F, 30 seconds immersion	.041	.025	.040
	SS 85 pounds per 100 gallons, 110 degrees F, 20 seconds immersion	.016	.024	.021
	SS 32 pounds per 100 gallons, 65 degrees F, 20 seconds immersion	.123	.157	.167
I	Rubber roller flotation washing machine			
	SS 80 pounds per 100 gallons, 105 degrees F, 60 seconds immersion	.015	.020	.015

made. Direct comparisons of the lead residue removal, however, is made since comparable samples from each of the three spray programs were used.

Representative data from these experiments in lead residue removal from the apples receiving the three standard spray programs are in Tables II and III.

The data in Tables II and III indicate that the apples sprayed with lead arsenate in combination with a soap spreader or with lead arsenate and mineral oil and fish oil emulsified with oleic acid or sodium silicate, or with lead arsenate and kerosene soap, can be effectively washed with the better flood or agitation types of the commercial tandem washers utilizing both sodium silicate and hydrochloric acid washing solution. The degree of agitation and abrasion afforded is important since the dipping tank with step over types of washing machines as shown in Group A lacking agitation are not as efficient in reducing the lead residue even with greater concentrations of materials and longer time allowed for fruit in solutions. The degree of agitation and scrubbing afforded the fruit increases with each of the types of washing machines listed in sequence from Group A to E inclusive. Their effectiveness in cleaning is also increased in the same order, until the cleaning becomes very effective with the machine in Group E which is the Experiment Station Fruit Washer. The machine is so constructed as to permit the handling of adequate foam developed by the addition of liquid vegetable soap which facilitates the thorough wetting of the fruit surface. The machine gives an abrasive action with underneath revolving brushes; each tank is provided with a heavy forceful overhead flood system of agitation; it has good temperature control; and finally has excellent rinsing facilities. Furthermore, with the tolerance of .019 or with the proposed tolerance of .018 for lead, the single type of washing machines do not appear to

be effective as shown by the data in Table III. As comparable spray programs may become increasingly used for codling moth control and with the present lead residue tolerance of .018, this would indicate that a larger percentage of the apple crop will be washed in central packing houses where the better tandem washing machines are available. This would be true except possibly in the case of the very large growers who could afford to have the latest improved washing equipment.

Lead Residues and Their Removal as Influenced by Spray Programs

By M. H. HALLER, *U. S. Department of Agriculture*, J. H. BEAUMONT, *University of Maryland, College Park, Md.*, and C. W. MURRAY, and C. C. CASSIL, *U. S. Department of Agriculture, Washington, D. C.*

WITH the establishment of a regulatory tolerance for lead (0.020 grain per pound of fruit) in 1933, many fruit growers throughout the East turned to substitute sprays for lead arsenate or to restricted spray programs. These efforts to avoid washing usually resulted in increased worm infestation and were found by experience to be uneconomic. This has caused a return to a more adequate program of lead arsenate sprays and the necessity of washing to remove the excessive residue. Since many growers are now equipped to wash their fruit, it should be possible to follow more effective spray programs than are usually recommended.

The investigations reported here were undertaken in 1934 to determine to what extent certain modifications of the spray program that might increase its effectiveness would influence the amount of residue on the fruit at harvest or the difficulty of removal.

MATERIALS AND METHODS

The fruit for these investigations was grown near Frederick, Maryland, and Kearneysville, West Virginia[1]. At Frederick, Maryland, four varieties of apples (Jonathan, Grimes Golden, Delicious, and Stayman Winesap) were given differential spray treatments consisting of five and seven cover sprays of lead arsenate, 3 pounds to 100 gallons. To certain of the five-cover-spray plots fish oil (1 quart to 100 gallons) or mineral-oil emulsion (1 gallon to 100 gallons) was added in early and late cover sprays. Because of the use of oil in some of the early cover sprays, Bordeaux mixture was used as the fungicide during the entire season. At Kearneysville, West Virginia, two varieties of apples (Stayman Winesap and York Imperial) were sprayed with five and seven cover sprays of lead arsenate, 3 pounds to 100 gallons, with fish oil (1 quart to 100 gallons), mineral-oil emulsion (1 gallon to 100 gallons), or casein-lime spreader (1 pound to 100 gallons) added to the second-brood cover sprays (fourth and subsequent sprays). The usual fungicides were added to these sprays.

To reduce the sampling variability, the apples were sorted and only the medium-sized fruit was used. The fruit was held at 32 degrees F until the washing treatments could be given, which was usually within a week of picking. For the washing treatments a flotation-type washer having a false floor and a slat conveyor that pushed the fruit through the solution was used. The time of exposure to the wash solution was one minute.

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[1]The cooperation of Mr. E. Gould and his associates of the Bureau of Entomology and Plant Quarantine, who were responsible for the spray plots at Kearneysville, is gratefully acknowledged.

Samples consisted of 60 to 90 apples for unwashed lots, and of 30 to 50 apples for washed lots. Analyses were made in duplicate or triplicate, 15 to 30 apples being used for each analysis[2]. Since the ratio of lead to arsenic trioxide in the residues from lead arsenate sprays is almost invariably in excess of 2 to 1, while the ratio of their tolerances is less than 2 to 1, any treatment that effectively removes the lead can be assumed to be effective for arsenic. For this reason, lead only was determined. The consequent saving in time permitted of more extensive removal investigations than would have been possible if both lead and arsenic had been determined.

The method used for determining the lead in these samples may be very briefly described as follows:[3] The peels from each sample of 15 to 30 apples were heated with concentrated nitric acid until they were completely "mushed" and showed little or no stringiness. The mush was then made to volume and filtered, after which a suitable portion of the filtrate was made ammoniacal and extracted with a chloroform solution of diphenyl thiocarbazone. The chloroform solution, which contained the lead, was evaporated to dryness and heated with a little concentrated nitric acid to destroy the organic lead compound, after which the solution was diluted and electrolyzed between platinum electrodes. The deposit of lead peroxide was dissolved from the anode by means of a solution containing potassium iodide, and the liberated iodine titrated with standard thiosulphate solution.

Results

The lead residues at harvest and after certain washing treatments are presented in Table I. The results from only two varieties of apples from Frederick are included, as similar results were obtained from the other two varieties treated. The plot with five cover sprays of lead arsenate plus a fungicide corresponds closely to common commercial practice in the East and is used as a standard for comparison with the other plots.

The results show that the addition of either fish oil or mineral oil to the first two cover sprays has not increased the amount of residue at harvest or increased the difficulty of removal.

Although the results for Jonathan apples indicate a lower residue at harvest with the addition of fish oil in the first two covers, the other varieties from Frederick, Maryland, do not show any such reduction in residue.

The addition of fish oil to the second-brood cover sprays usually increased the amount of residue at harvest but did not make removal more difficult with the fruit from either Frederick, Maryland, or Kearneysville, West Virginia. Likewise the addition of casein-lime spreader to the second-brood sprays at Kearneysville usually increased the load at harvest but did not increase the difficulty of removal.

[2]The writers wish to give credit to H. D. Mann, of the Insecticide Division, Bureau of Entomology and Plant Quarantine, for his great assistance in the preparation of the samples for chemical analysis.

[3]This is a modification of the method described by Wichmann, Murray, Harris, Clifford, Loughrey, and Vorhes. Jour. Assoc. Off. Agr. Chem. 17: 108–135. 1934.

TABLE I—RELATION OF SPRAY TREATMENTS TO LEAD RESIDUES AT HARVEST AND AFTER VARIOUS WASHING TREATMENTS. ALL RESULTS IN GRAINS OF LEAD PER POUND OF APPLES

Spray Treatments		Lead Residues Following Washing Treatments			
No Cover Sprays of L. A.[1]	Additional Material	Not Washed	0.5 Per cent HCl, Room Temp.	1.5 Per cent HCl, Room Temp.	1.5 Per cent HCl, 100 Degrees F
	Jonathan (Frederick, Maryland)				
5........	———	.049	.013	—	—
5........	F. O.[2] in 1, 2	.036	.012	—	—
5........	F. O.[2] in 1, 2, 4, 5	.052	.012	.008	—
5........	M. O.[3] in 1, 2	.044	.014	—	—
5........	M. O.[3] in 4, 5	.086	.025	.016	.016
5........	M. O.[3] in 1, 2, 4, 5	.084	.024	.017	.015
7........	———	.066	.018	—	—
	Grimes Golden (Frederick, Maryland)				
5........	———	.059	.018	—	—
5........	F. O. in 1, 2	.061	.016	—	—
5........	F. O. in 1, 2, 4, 5	.071	.015	.012	—
5........	M. O. in 1, 2	.057	.018	—	—
5........	M. O. in 4, 5	.089	.026	.016	.014
5........	M. O. in 1, 2, 4, 5	.086	.026	.018	.013
7........	———	.060	.014	—	—
	Stayman Winesap (Kearneysville, West Virginia)				
5........	———	.058	.024	.017	—
5........	C. C. S.[4] in 4, 5	.070	.025	—	—
5........	F. O. in 4, 5	.070	.026	.014	.012
5........	M. O. in 4, 5	.077	.032	.020	.014
7........	———	.103	.036	.020	.016
7........	C. C. S. in 4 to 7	.122	.034	.019	.016
7........	F. O. in 4 to 7	.128	.043	.021	.015
7........	M. O. in 4 to 7	.137	.052	.029	.026
	York Imperial (Kearneysville, West Virginia)				
5........	———	.056	.023	.016	—
5........	C. C. S. in 4, 5	.066	.023	—	—
5........	F. O. in 4, 5	.075	.024	.018	.012
5........	M. O. in 4, 5	.092	.038	.027	.018
7........	———	.115	.046	.020	.014
7........	C. C. S. in 4 to 7	.108	.030	.017	.014
7........	F. O. in 4 to 7	.115	.034	.017	.014
7........	M. O. in 4 to 7	.168	.052	.035	.030

[1]L.A. = Lead arsenate 3 pounds to 100 gallons.
[2]F.O. = Fish oil 1 quart to 100 gallons.
[3]M.O. = Mineral-oil emulsion 1 gallon to 100 gallons.
[4]C.C.S. = Casein-lime spreader, 1 pound to 100 gallons.

The addition of mineral oil to the second-brood cover sprays in all cases greatly increased the amount of residue at harvest and also made cleaning considerably more difficult.

The washing treatment required to condition the fruit varied with the spray treatment, variety of apple, and locality where grown. When washed with 0.5 per cent hydrochloric acid at room temperature, the residue on all lots of Jonathan and Grimes Golden from Frederick, Maryland, was brought to below the tolerance except on the apples from the plots that had mineral oil in the late cover sprays. This same washing treatment was ineffective with either Stayman Winesap or York Imperial from any of the spray plots at Kearneysville. When the acid concentration of the washing solution was increased to 1.5

per cent at room temperature, the Jonathan and Grimes Golden apples from the plots with late cover sprays of lead arsenate and mineral oil were cleaned to within the tolerance. This treatment was, however, ineffective on the comparably sprayed Stayman Winesap and York Imperial apples from the plots at Kearneysville, West Virginia, or on any of the apples from the seven-cover-spray plots at Kearneysville, but was effective on apples from the five-cover-spray plots other than those receiving a spray containing mineral oil. With 1.5 per cent hydrochloric acid heated to 100 degrees F, the apples from all the Stayman Winesap and York Imperial plots except those receiving the seven cover sprays containing mineral were cleaned to within the tolerance. It might be mentioned in this connection that with the addition of Vatsol to the above washing solution the apples from these plots also were brought to within the tolerance. (Results not given.)

Discussion

The amount of residue at harvest, and consequently the ease of cleaning following a given spray program, may vary considerably, depending on the weather conditions prevailing during the growing season. The season of 1934 was abnormal in that the early part of the season was unusually dry and in the latter part, particularly September, the rainfall was greatly in excess of normal. A comparison of the results in 1934 with those in 1933 indicates that with similar spray schedules of lead arsenate the residues at harvest were about the same both seasons but that their removal was considerably more difficult in 1934. Thus, all the experimental lots in 1933 that received five cover sprays of lead arsenate were cleaned to less than 0.01 grain of lead per pound by washing with 0.5 per cent hydrochloric acid at room temperature, whereas with the same washing treatment in 1934 the residue on similarly sprayed fruit was in all cases above 0.01 grain per pound and was even in excess of the tolerance on the apples from Kearneysville. This indicates that with hydrochloric acid at room temperature more effective cleaning than that obtained in 1934 might normally be expected.

Summary

The results of spraying and washing investigations in the Shenandoah-Cumberland Valley in 1934 indicate that fish oil or mineral oil might be added to the first two lead arsenate cover sprays without influencing the amount of residue at harvest or its removal.

The results indicate that the addition of mineral oil, fish oil, or casein-lime spreader to the late cover sprays of lead arsenate increases the residue at harvest, particularly so in the case of mineral oil. The difficulty of removing the excessive residue was greatly increased by the addition of mineral oil to the late cover sprays but was not appreciably influenced by the addition of fish oil and casein-lime spreader.

The application of seven cover sprays increased the amount of residue at harvest and the difficulty of removal as compared with that following five cover sprays.

Relative Value of Several Wetting Agents in Removing Lead Residues from Apples

By J. H. BEAUMONT, *University of Maryland, College Park, Md.*, and M. H. HALLER, *U. S. Department of Agriculture, Washington, D. C.*

SEVERAL wetting agents have proven quite helpful in aiding the removal of spray residues of arsenic and lead from fruit, when used in acid washing solutions. Little is known of the rôle the wetting agent plays in fruit washing and until such information is available it will be necessary more or less arbitrarily to select and to test those that may appear to have some promise. The present report covers the results of such a test. It serves to emphasize the need of fundamental research on the problem of wetting agents in fruit washing.

Seven wetting agents furnished by the manufacturers were included in the test. Approximately 1 per cent solution of each was tested in 1½ per cent HCl, at two temperatures (70 degrees F and at 100 degrees F) and in 1½ per cent HCl plus 1 per cent salt at each temperature. The time of immersion in the solution was one minute. A Wayland flotation washer having seven horizontal rows of brushes to submerge and rotate the fruit in the acid tank, two rows in the rinse tank and a towel drape dryer was used. Previous experience had shown the flotation type washer to be quite efficient and suitable for the experiments contemplated.

The test fruit was of two varieties, Grimes Golden and York Imperial, each variety representing two spray programs. The Grimes Golden received five cover sprays of arsenate of lead, 3 pounds per 100 gallons, to which 1 quart of fish oil or 1 gallon of mineral oil was added in the last two covers. The York Imperial received seven cover sprays of arsenate of lead, 3 pounds per 100, to which 1 quart of fish oil or 1 gallon of mineral oil was added in each of the last four cover sprays. A fungicide, usually Bordeaux mixture, was added to all sprays. These spray programs were selected because it was thought that fruit difficult to clean would give a better relative measure of the efficiency of the various wetting agents. The samples for washing and for lead analysis were taken as described in the preceding paper (1).

The analytical method for the determination of lead used by the U. S. Department of Agriculture has been described (1), while that used by the Department of Horticulture, University of Maryland, was essentially that described by Frear and Haley (2). The two methods checked very closely. The average difference was less than .003 gr/lb in this series of analyses, the Maryland results generally being lower than those of the U. S. Department of Agriculture[1]. The results are a compilation of the analyses made by the two agencies. The "no wetting agent" and Vatsol determinations are the average of analyses made by both agencies. The results with two other wetting

[1]The analyses of the U. S. Department of Agriculture were made by C. W. Murray and C. C. Cassil, of the Bureau of Entomology and Plant Quarantine.

agents (Hydrin A, Igepon T) are those of the U. S. Department of Agriculture and the results of the four remaining are those obtained by the Maryland Department of Horticulture.

Fisher's (3) method of analysis of the data was employed which made it possible to evaluate the effects of the various factors, such as temperature, salt, oil, etc., used in testing the wetting agents as well as the effect of the wetting agents themselves. Snedecor's (4) adaptation of Fisher's "Z" test of significance, which is simpler to calculate, was used to test the significance of the differences between the different variances, and the discussion following was based on this test of significance of the data. The calculations presented are based on the actual amounts of lead found after washing (Table I), and also on percentages of the total lead before washing (Table II). The latter method of presentation brings out certain facts more forcibly than the former, particularly since the residue remaining after washing treatment is highly correlated with the residue before washing. Other important differences will be indicated in the following discussions. It must be recalled that by this treatment all the data were used. For example in comparing the two temperatures all of the analyses (64 in number) at each temperature on the lots of fruit washed in the different solutions were averaged. The mean square or variance is the average of the squared deviations from the means at the two temperatures. The ratio of this variance over the variance for error is then compared with the ratio found in Snedecor's table of F under the appropriate numbers for degrees of freedom. Should the ratio exceed that found in the table of 5 per cent or of one per cent points it is concluded that the chances are less than one in 20 or one in 100 respectively that the variances are due to errors of random sampling.

TABLE 1—Analysis of Variance of the Effectiveness of Wetting Agents in Removing Lead Residues from Apples Sprayed with Four Different Spray Programs and Washed in 1½ Per Cent HCl at Two Temperatures and With or Without Salt (Analysis Based on Actual Quantities of Lead in gr/lb).

Source of Variance	Degrees of Freedom	Variance or Mean Square	Ratio Source/Error	Ratio Required for Significance Snedecor's F.‡
1 Temperature 70 degrees F vs. 100 degrees F	1	820.1250	15.81	*6.90
2 No salt vs. 1 per cent salt	1	5.2812	——†	——
3 Mineral oil vs. fish oil	1	840.5000	16.21	6.90
4 Wetting agent treatments	7	191.1429	3.69	2.83
5 Salt x temperature	1	0.0313	——	——
6 Oil x temperature	1	72.000	——	——
7 Wetting agents x temp	7	7.8393	——	——
8 Wetting agents x oil	7	38.9286	——	——
Remainder error	101	51.8632	——	——
Total	127	——	——	——

*Ratios are the closest in the 1 per cent table. Differences are so great it was unnecessary to interpolate.

†Blank spaces indicate the variances are less than that required for significance and are not calculated.

‡Ratio required to show significant effect of treatment.

TABLE II—ANALYSIS OF VARIANCE OF THE EFFECTIVENESS OF WETTING AGENTS IN REMOVING LEAD RESIDUES FROM APPLES SPRAYED WITH FOUR DIFFERENT SPRAY PROGRAMS AND WASHED IN 1½ PER CENT HCl AT TWO TEMPERATURES AND WITH OR WITHOUT SALT
(Analysis Based on Percentage of Original Lead)

Source of Variance	Degrees of Freedom	Variance or Mean Square X10⁶	Ratio Source/Error	Ratio Required for Significance Snedecor's F.‡
1 Temperature 70 degrees F vs. 100 degrees F	1	652.5078	98.05	*6.90
2 No salt vs. 1 per cent salt	1	1.7578	——†	——
3 Mineral oil vs. fish oil	1	8.5078	——	——
4 Wetting agent treatments	7	119.1060	17.90	*2.84
5 Salt x temperature	1	0.0078	——	——
6 Oil x temperature	1	31.0078	4.70	§3.94
7 Wetting agent x temp	7	7.4185	——	——
8 Wetting agent x oil	7	13.1328	——	——
Remainder error	101	6.551	——	——
Total	127	——	——	——

*Ratios are the closest in the 1 per cent table. Differences are so great it was unnecessary to interpolate.
†Blank spaces indicate the variances are less than that required for significance and are not calculated.
‡Ratio required to show significant effect of treatment.
§Ratio required for odds of 1:19.

Wetting agents:—In Tables I and II the variance for wetting agent treatments (Line 4 in tables) exceeds that required for significance of odds of 1:99. Especially is this true when percentages of residue remaining are considered. The wetting agent treatments, therefore, were not equal in effecting the removal of the spray residues. The mean values for the 16 lead determinations with each wetting agent are given in Table III.

TABLE III—ACTUAL AMOUNTS AND PERCENTAGE OF LEAD RESIDUES REMAINING ON FRUIT AFTER WASHING WITH VARIOUS WETTING AGENTS. THE MEANS REPRESENT FOUR SPRAY PROGRAMS AND FOUR WASHING TREATMENTS WITH EACH WETTING AGENT

Wetting Agents	Check Unwashed (Grain per Pound)	Lead Residue after Washing (Grain per Pound)	Per Cent of Unwashed Check*
No wetting agent	.1094	0.0183	16.4
Igepon T	.1107	0.0191	16.3
Hydrin A	.1107	0.0183	15.1
Vatsol	.1094	0.0117	10.6
Areskat	.1082	0.0126	11.2
Ammonium sulfosoap	.1082	0.0137	12.4
Nekal B	.1082	0.0124	11.9
DuPont No. 2	.1082	0.0103	9.4
Standard error of the means	——	0.0018	0.64
2 x the standard error of the difference	——	0.0051	1.82

*Check and consequently the percentages will vary slightly according to whether the analyses for lead are composited as indicated in previous paragraphs.

The standard error of the means and two times the standard error of the difference have been calculated by the usual formulae from

the remainder variance for error in Tables I and II. The latter furnishes a convenient minimum value to be used in approximating the significance of the difference between any two values in the column above. It will be noted that the errors for the means of the actual and percentage values are approximately 13 per cent and 5 per cent respectively. The latter figure indicates that a great deal of the variability in the results has been eliminated by compensating for the residue carried on the fruit before washing.

It is quite apparent that the two wetting agents, Igepon T and Hydrin A were no better than no wetting agent. Ammonium Sulfosoap was intermediate and four of the wetting agents, Vatsol, Areskat, Nekal B, and DuPont No. 2, were distinctly beneficial in removing the residues. However, other considerations must be taken into account in considering these latter five wetting agents.

Ammonium Sulfosoap while apparently quite stable at lower temperatures broke down, leaving a tar-like coating in the wash tank, when heated with a steam jet. It is doubtful how long it would have remained effective in removing residues even though the deposit were not objectionable. DuPont No. 2 was apparently one of the most effective wetting agents from the standpoint of removing the lead residues. However, the York Imperial samples receiving seven cover sprays with mineral oil in four were severely burned in the heated solutions not containing salt when this wetting agent was used. The heated solution containing salt did not burn this sample. The Grimes Golden samples were not injured nor was the York Imperial sprayed with fish oil. Since both varieties were washed in the same solution and at the same time, it appears that there may be a relationship between the spray program, temperature, salt and wetting agents, causing burning. That it was not a chance occurrence is evidenced by the fact that the sample of York Imperial injured with Du Pont No. 2 also was injured when Areskat was used. Here the injury was of the same type but milder and occurred in the heated solutions both with and without salt. Both wetting agents were effective in aiding in the removal of the residues, however. The apparent association of fruit injury with wetting agent, type of oil, and temperature, adds another complication to the spray residue problem.

No injury was found following the use of Vatsol, or Nekal B and both were effective in aiding in the removal of the residues.

The efficiency of the wetting agents, as a group was not affected by the type of oil used in the spray program as may be seen from the interaction of wetting agent x oil (Line 8 in the tables). Also, the interaction of wetting agent x temperature (Line 7 in the tables) does not indicate that the wetting agents differ in their effectiveness at the two temperatures.

The data here presented are insufficient to warrant discussion of other specific characteristics of particular wetting agents. Wetting agents differ chemically and it may be expected that some may have specific requirements both as to the temperature and other characteristics of the washing solution and as to the characteristics of the residue carried on the fruit. These problems will be discussed in later reports.

The effect of increasing the temperature of the wetting agent solutions from 70 degrees F to 100 degrees F (Line 1 in tables) was significant. This was true whether actual amounts or percentages were calculated and demonstrate that temperatures of wetting agent solutions between 70 and 100 degrees have a marked influence in affecting the removal of spray residues of this type. The mean values for lead after washing at 70 and at 100 degrees are 0.0171 gr/lb and 0.0120 gr/lb respectively, and for the percentages 15.1 and 10.6 per cent of the original residues.

Salt has had no measureable effect on the removal of the oil-lead arsenate spray residues when used in the wetting agent solutions (Tables I and II, line 2). Moreover, the interaction of salt and temperature (Line 5 in the tables) is not significant when considered either as actual residues or as percentages. The salt, therefore, is neither beneficial at the lower temperature nor at the higher, or conversely the effect of the temperature is not dependent on the presence or absence of one per cent of salt. Other interactions such as that of oil x salt were calculated and found to be of no significance. These are included in the remainder variance or error.

The fruit used in the wetting agent tests was sprayed with fish oil or mineral oil. The mineral oil greatly increased the lead residue at harvest (1), and in Table I, line 3, is seen the effect of the oils on the lead remaining after washing with the wetting agent solutions. The mineral oil sprayed fruit carried significantly heavier residues after washing than fish oil sprayed fruit when all the washing treatments were averaged, (.017 and .012 gr/lb, respectively).

An examination of the data of the individual lots and treatments shows that these differences were particularly marked with relatively ineffective washing treatments and that with the more effective treatments the residues on mineral oil and fish oil sprayed fruit tended to be removed to low values that were approximately equal.

With approximately equal amounts of residue after washing the percentage of the original load remaining would be less on the mineral oil sprayed fruit because of the greater original load on this fruit. Since heating greatly increased the effectiveness of the washing treatments it might be expected that with heated solutions a greater percentage of the residue would generally be removed from the mineral oil sprayed fruit. The data indicate that this was so as the interaction of temperature x oil in Table II, line 6, gave odds somewhat greater than 1:19 that the residues accompanying the two oils were not removed at the same rate at the different temperatures. At the higher temperature a greater percentage (5.5 per cent) of the residue was removed from the mineral oil sprayed fruit and at the lower temperature a greater percentage (3.5 per cent) was removed from the fish oil sprayed fruit. In many instances, however, relatively effective treatments at room temperature did not remove a greater percentage of residue from the fish oil sprayed fruit and in other instances relatively ineffective treatments even though heated did not remove a greater percentage of residue from the mineral oil sprayed fruit. Such variations were to be expected and it has been pointed out that the error of a single determination which includes the errors of

sampling and of analysis, as well as other undetermined variations, was quite large.

On a percentage basis, it is seen, Table II, line 3, that when all of the washing treatments were averaged the residues were removed at the same rate regardless of the type of oil used in the sprays. This is to be expected if, as indicated above, with some washing treatments a greater percentage of the residues was removed from the mineral oil sprayed fruit and with other washing treatments a greater percentage was removed from the fish oil sprayed fruit.

Since 0.019 gr/lb was the tolerance for lead the problem must be approached from this base and the percentage to be removed to reach this figure will necessarily vary with the original load carried on the fruit. The efficiency of the washing solution should be adjusted to meet the specific requirements of any lot of fruit and this will depend in large measure on the total amount of lead present. To vary the efficiency of the wash should not be difficult when accurate information is accumulated on the characteristics of various types of residues and the relative value of the many factors affecting the efficiency of the washing solution.

Under the conditions of and from the results of this test of the wetting agents the following conclusions may be drawn:

1. Not all wetting agents were effective in aiding in the removal of lead residues. Two of those tested had no beneficial effect, one was intermediate, and four were quite effective. Of the four effective wetting agents, two caused injury at a temperature of 100 degrees F to the sample of York Imperial apples that were sprayed with seven cover sprays of arsenate of lead, the last four covers containing one gallon of mineral oil per 100 gallons.
2. An increase in temperature of the wetting agent solutions from 70 to 100 degrees F was tremendously effective in increasing the efficiency of the wash.
3. The fish and mineral oils used with arsenate of lead affected the residues at harvest and also the removal of the residues by the wetting agent solutions. The wetting agent washing solutions on the average removed both types of residue equally effectively. However, there was a tendency for these solutions to remove greater percentages of the mineral oil-lead aresnate residues at the higher temperature presumably because the heavier residues responded to this treatment while the fish oil-lead arsenate residues were effectively removed at the lower temperature and had more nearly reached the amount capable of being removed by washing treatments. Consequently the residues accompanying fish oil could not show the effect of the more effective heated treatment to the same extent as the mineral oil-lead arsenate sprayed fruit.
4. One per cent of salt had no effect whatever in the wetting agent solutions, and might be omitted unless proven to be effective with a specific wetting agent.
5. The interaction of wetting agent x temperature was not significant, and indicates that these factors were purely additive in increasing the efficiency of the washing solution.

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The Isolation and Propagation of High Pyrethrin Strains of Pyrethrum[1]

By Brooks D. Drain, and G. A. Shuey, *Tennessee Agricultural Experiment Station, Knoxville, Tenn.*

RESEARCH work with *Pyrethrum cinerariaefolium* in this country is a recent development, with comparatively few data upon which to base conclusions and theories. Work has begun on this crop at the Tennessee Station in 1928, and several reports on the project have already appeared in print (1).

The first plantings were made with seed from various foreign countries, such as Dalmatia, Japan, Switzerland, France, and England. Plant characters, including time of blossoming, height of flower stalk, tendency to lodge, and size of blossom varied greatly both among the different lots of seedlings and within a given lot. These observations and some preliminary analyses suggested the possibility of selecting superior commercial strains. The plan called for several years' work, as pyrethrum is commonly propagated from seed.

Two methods of analyzing air-dried blossoms have been used. The first was a semi-quantitative method, based on the reducing power of pyrethrins, contained in a resin extracted with petroleum ether, on an alkaline copper solution, and could be used on small amounts of the material to be analyzed. The flowers from 84 individual plants that had previously been selected for superior plant characters were analyzed by this method, and nine plants were found to contain more than 1.2 per cent total pyrethrins, whereas eleven contained less than 0.6 per cent. The copper reduction method of Gnadinger and Carl (2) was used on 39 samples from progeny rows and selected individual plants. A progeny row was secured by asexual propagation of a single selected individual plant. Thirteen samples contained over 0.9 per cent of pyrethrins I and II; 18 analyses showed a content less than 0.7 per cent; the lowest content was 0.51 per cent, and the highest 2.05 per cent.

Crown division tests were started in 1932 as a means of developing progeny rows of selected individual plants, and this method at once appeared to be as economical as the usual method of seed reproduction where the seedlings are grown in a frame and transplanted to the field. Crown divisions made in the fall, managed in a frame during the winter and set in the field in the spring, averaged 83 per cent of a stand at the end of the first season, with many of the progeny rows having a perfect stand. A similar set of crown divisions were made on March 6 and set at once in the field. Some of these progeny rows failed to grow at all and the best showed an 84 per cent stand. An examination of the roots of these asexually propagated plants during hot and dry periods in the spring indicated that fall crown division gave a larger root system. Individual plants vary, as to ease of propagating asexually, both in the number of divisions that can be made from a single crown and in the per cent rooting. The larger and more easily propagated crowns made over 100 plants each.

[1]A joint contribution from the Departments of Horticulture and Chemistry.

A single plant having blossoms that analyzed high in total pyrethrins was propagated vegetatively in 1932 and the air-dried blossoms from its progeny row analyzed 2.05 per cent in 1934. In addition, this row yielded at the rate of 1,088 pounds of dried blossoms per acre. This suggests that pyrethrin content, while influenced, possibly, by environmental factors, is also more or less genetic in nature. It is of interest to note that the highest pyrethrin content of the blossoms from an individual plant as reported by the Colorado Station (3), was 2.07 per cent on a moisture-free basis, and that this was approximately the same as reported above. Gnadinger's (4) analyses of pyrethrum blossoms grown in various parts of the United States show lower pyrethrin content in those from Michigan and Minnesota than in those from the more southern regions. Such regional comparisons should be made with a single vegetative strain rather than with unclassified seedling plants.

The authors wish to emphasize the importance of the high pyrethrin content, as well as superior plant characters, in selections made to improve this crop. Such selections can then be propagated asexually to reduce the variation within a strain to a minimum. Crown division appears to be the more feasible of these asexual methods for this crop.

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Two Problems Facing Teachers of Horticulture[1]

By R. J. Barnett, *Kansas State College, Manhattan, Kans.*

THE writer of this brief discussion does not purpose to open up the general subject of courses and curricula in horticulture but rather to call attention to two important phases of it and to suggest the desirability of greater uniformity and possible improvement in these particulars. The whole subject of college instruction in horticulture might at some later meeting be the assigned topic for an extensive symposium. Except for Professor F. C. Bradford's paper presented in 1921, the casual reader of the Proceedings of the Society would gain the impression that teaching of horticulture ceased to interest the members about 17 years ago when the last report of the committee on undergraduate work was made. However, it is probable that this assumption would be only partly true. The best practices known at that time had received wide discussion and textbooks superior to those in other lines of agriculture had become available. These advances produced a period of high performance despite the lack of extensive discussion.

Under present conditions as they affect horticulture, the instruction of undergraduate students in the colleges of agriculture remains the primary function of departments of horticulture in such colleges. Routine correspondence, supervising the studies of graduate students, experimental work and original research all have their place in such departments but the emphasis on them should not be so strong as to detract from the amount or the quality of undergraduate instruction in either classroom or laboratory. If such neglect should occur it would result in drying up the sources from which the future supply of professional horticulturists comes. The force of the statement that the greater part of undergraduate work for potential horticulturists should consist of fundamental science is apparent, but, alas, experience shows that the art of horticulture is rarely learned by a graduate student.

Students of agriculture prepare for many lines of highly important work in which they will need knowledge of both the science and art of horticulture. General farming, high school teaching of agriculture, farm bureau agent work, and credit advisors are examples. Since even a 5-hour beginning course will fail fully to satisfy their need, an additional course which may or may not be acceptable for major students in horticulture should be provided for them. An elementary knowledge of intensive agriculture as exemplified in pomology and olericulture is a practical necessity for all students of agriculture.

The following discussion will center on two questions: What is the status of the beginning or required course in horticulture? And, in what undergraduate courses in horticulture should major students enroll? Correct answers to both of these questions would seem important to the future welfare of American horticulture.

[1]Contribution No. 130, Department of Horticulture.

THE BEGINNING OR REQUIRED COURSE IN HORTICULTURE

The function of the beginning or required course in horticulture is to introduce the student of agriculture to the intensive type of crop production. Many of the underlying principles and much of the art differ from the science and art of field crop production.

The minimum prerequisites for this course should be freshman botany, chemistry, and soils. The last might be a concurrent course. A knowledge of elementary plant physiology would be desirable, for both the student and the instructor. These requirements would locate the course in the sophomore year.

The best content for this course is not easily determined and possibly should vary for the different sections of the country. However, if the name horticulture is to apply to it, the minimum number of divisions would seem to be two, pomology and olericulture. To these could be added plant propagation, floriculture, greenhouse management, and ornamental plants, all gardening or horticulture but, obviously, covering too much material for even elementary or outline treatment in a three semester hour course.

A study of catalogs from 15 representative land grant colleges, both universities and state colleges, revealed the following data regarding this course: In all but one school it is a 3-hour course; 11 require all or nearly all students of agriculture to enroll in the course, and in only two is it wholly elective; eight departments list the course for sophomore or junior students and seven for freshmen. The name and apparently the content of the course are very diverse. Sample names are: General plant propagation and tree fruit culture; Culture and Marketing of Horticultural Crops; Principles of Fruit, Vegetable, and Ornamental Plant Growing; Elements of Horticulture; General Plant Science; Growing and Handling Fruits and Vegetables; History of Horticulture; and Principles of Horticulture.

If greater uniformity is desirable the writer would submit that, as a name, "Elements of Horticulture" is suggestive and inclusive, that both fruit and vegetable production should be included, and that the course should be planned for the needs of all students of agriculture. It should be of genuine college grade. It should have but one teacher and he a horticulturist, rather than a pomologist or vegetable gardener, and the most skillful instructor in the department. A good text book would be desirable but, even if available, would leave much material of great local importance to be given by the instructor.

In many schools a large part of the laboratory exercises connected with this course should be given in the orchard or the garden and should consist of manual arts related to the garden crops and studies of land and plant values, garden pests, preparation of products for market and other practical exercises. The class instructor should at all times be in close touch with the laboratory work if he does not himself conduct it.

THE UNDERGRADUATE CURRICULUM IN HORTICULTURE

The study previously mentioned adduced certain additional particulars regarding courses in horticulture offered by the various institutions. In a large majority of these schools the work in horticul-

ture for major students of pomology or olericulture begins the first term or semester of the junior year. In only two, is the major department chosen at the beginning of the sophomore year.

An attempt was made to determine the number of semester hour credits in horticulture required of a major student. Some of the catalogs are indefinite on this item but many of them state the minimum requirement. The variation, omitting two schools which make no statement, is from 11 to 32 semester hours; the average, 19 hours. The maximum, 32 semester hours, would seem necessarily to reduce the hours of either cultural studies or fundamental science below the limit of tolerance.

An analysis of the courses offered in horticulture by these same schools was made, the basis being their classification as offering credit for undergraduates only or for both undergraduate and graduate students. The extremes for undergraduate courses are 3 and 65 semester hours and for the "200" group of courses 0 (by 4 institutions) and 47 semester hours. Averages were: "100" courses, 25 hours; "200" courses, 17.5 hours. Research and thesis were the only courses offered for graduate students only.

These wide variations raise the question, "For whom are these curricula devised?" Among the principal groups will be (1) those who expect to become professional horticulturists and are preparing for graduate work, (2) those who require a knowledge of general agriculture, such as farm bureau agents and high school teachers, and (3) those who plan to become operative horticulturists. Under the elective system, the arrangement of a curriculum fitted to the needs of each student would seem simple. The student would state his plans and ambitions and the elective courses best suited to prepare him would be placed on his to-do-list. But here arises a problem; the student after graduation may not engage in the type of work for which he prepared.

An analysis of records of 50 consecutive graduates of the Department of Horticulture, Kansas State College, will illustrate the situation. The present occupations of these graduates who majored in pomology or olericulture and the work in preparation for which they chose their elective courses are shown in Table I.

TABLE I—PROPOSED AND ACTUAL OCCUPATIONS OF FIFTY GRADUATES IN HORTICULTURE, KANSAS STATE COLLEGE

Occupations	Proposed Line Number	Actual Employment Number
Production (fruits or vegetables)	22	11
Professional (college)	15	13
Extension (agriculture)	1	8
U. S. D. A.	5	4
Federal emergency work	0	6
High school teaching	5	3
Miscellaneous*	2	5
Total	50	50

*Proposed—One each plant explorer and U. S. Army; actual—two graduate assistants and, one ach as life insurance agent, filling station operator, and housewife.

Of the 50 graduates, only 24 are doing the work they planned to do when they chose their elective courses. The widest variations occurred among those who planned to grow fruit or vegetables and those who did not plan to engage in agricultural extension or federal emergency relief work. When a student elects a course planned to prepare him for horticultural production he is not, as a rule, prepared for graduate work because of lack of fundamental science and modern language or for work in agricultural extension because of the narrowness of his training in agriculture.

Consideration of these problems raises the question, "Should the majority of the departments seek to make pomologists, olericulturists, florists and nurserymen of their undergraduates or should they, in contrast, train them in horticulture—intensive agriculture in general—and the basic physical and biological sciences?" For many students the more general course would certainly prove advantageous. Reverting to the group analyzed in Table I: 20 of the 50 have earned a higher degree, namely, Ph. D., 2; M. A., 1; and M. S., 17. However, only 10 of these advanced degrees were based on horticulture as the major study, indicating again the desirability of a broad, rather than a narrow, undergraduate curriculum.

Without attempting to indicate the solutions of these problems, the writer would suggest that the time is ripe for the officers of the society to revive the committee on undergraduate work and open for general study and discussion questions relating to such work. It is the most important work done by horticulturists in the colleges and universities.

Some Studies in Chemical Preservation of Fruit Specimens[1]

By ELDRED HUNT, *University of Minnesota, St. Paul, Minn.*

SPECIMEN fruits for exhibition purposes are sometimes preserved beyond their normal season by the use of chemical solutions. At the University of Minnesota Fruit Breeding Farm, a collection of exhibition fruits was desired for reference purposes. In the summer of 1934 the present work was begun in an attempt to preserve such a collection.

No review of the scanty literature will be given in this paper, but acknowledgments are made of the contributions of Peterson (2) and Vacha (3) of the University of Minnesota and Mackenzie (1) of Kent, England. The formulae of these workers were tested, some modifications were suggested and new solutions were devised. The most valuable of the old and new formulae have been listed numerically and are referred to in the description of the preservation of various fruits.

In the case of all fruits well colored specimens in the "hard ripe" stage of maturity were carefully placed in a jar and covered with a "fixing" solution. When proper fixation of the pigments was attained, as evidenced by color changes, the fixing solution was poured off, the fruit washed, and the jar refilled with a "holding" solution. In some cases an intermediate "bleaching" solution was necessary to restore the proper brightness. Success in preservation of color depended largely on the removal of the first solution at exactly the proper time. In order to "fix" the color it was left as long as possible, but it was necessary to avoid too long exposure as the color tended to become too dull or dark. The proper stage could be determined only by experience. Each specimen was handled as an individual. It was found impossible to make up a standard solution for a particular fruit which would fill the needs of that fruit in every case. Instead, an approximate "stock" solution was made up in advance which had to be modified or replaced with another when the reaction of the specimen demanded.

After completion of the preserving process, all specimens were watched closely during the first month to make sure that the holding solution was properly balanced in all respects. In order to maintain this proper balance it was necessary that the specimen jars be sealed tightly, due to the volatile nature of various chemicals in the solutions.

Chemical preservation must accomplish three results, namely, prevention of fungus and bacterial growth, maintenance of shape, and preservation of natural color. Since the preserving solutions must act favorably as regards all three of these points, combining the ingredients necessitates a knowledge of the actions of the individual chemicals. The actions of the commonly used chemicals are as follows:

Formaldehyde:—Deepens the colors and also causes a "hardening" of fruit tissues.

[1]Paper No. 1328. Journal Series, Minnesota Agricultural Experiment Station.

Sulphurous acid:—Bleaches and softens fruit tissues and should be used in very low concentrations until the fruit pigments have been "fixed" and the tissues hardened by a previous solution.

Alcohol:—Dissolves out pigments but has a hardening effect on tissues. It is also useful as a solvent for other ingredients which do not dissolve directly in water.

Copper sulphate:—Replaces green color which has been destroyed by other chemicals. By varying the concentration it is possible to produce almost any desired shade of green.

Sodium chloride:—Increases the specific gravity of solutions so that only a small amount of the more costly glycerine is needed. It also has a hardening effect on tissues in general.

Methods of Handling Various Fruits

Plums

To prevent bursting of skins it was necessary to balance the specific gravity of the solutions used, with the specific gravity of the fruit. This "balancing" was done thru the addition of glycerine (5 to 20 cc per 100 cc of solution) until the plums rose from the bottom of the jar. The fruit was watched closely during the first 24 hours. If cracking was noted more glycerine was added at once, and if shriveling occurred more stock solution was added. The methods found best suited to the three color types were as follows:

A. Solid red:—Fixing solution No. 2 was used. When the plums began to show slight darkening (after 1 to 4 days), holding solution No. 8 was used. If solution No. 2 produced too dark color, it was followed by a short bleaching treatment with solution No. 10. When proper brightness was regained, holding solution No. 8 was then used.

B. Shaded red and yellow:—Fixing solution No. 1 was used for 12 to 48 hours, and then followed by holding solution No. 8. The change was made before much darkening of the fruit had taken place in order to prevent permanent masking of the delicate shading.

C. Solid yellow:—Fixing solution No. 3 was used for 2 to 7 days. This was followed by holding solution No. 8 for dark yellow plums and by solution No. 10 for light yellow plums.

Pears

A. Solid green or yellow:—Fixing solution No. 4 was used, followed by holding solution No. 9 after 3 weeks.

B. With russet or blush:—Fixing solution No. 5 was used, followed by holding solution No. 9 after approximately 3 weeks.

Apples

The fruits were very much darkened by the action of the paraffin oil solution used but the colors were restored by the bleaching solution. During the bleaching process the oil which had penetrated into the tissue appeared on the surface of the apples in the form of a film. This film was wiped off regularly with a dry cloth and fresh solution added. The more often the film was removed the shorter was the time required to restore the natural colors. The specific procedures made necessary by the various color types in apples were as follows:

A. Solid yellow:—Fixing solution No. 7 was used for approximately three weeks. Bleaching solution No. 12 was then used and when the color was bleached to the proper shade, it was followed by holding solution No. 13.

B. Solid green:—The procedure was the same as in A except that copper sulphate was added to solution No. 12 to restore the green color lost while in solution No. 7.

C. Red or yellow with red stripes or blush:—Fixing solution No. 7a was used followed in 3 weeks by bleaching solution No. 12. Holding solution No. 13 was used when natural color was regained (2 to 4 weeks).

D. Green with red stripes or blush:—Procedure was as in C with the addition of copper sulphate to solution No. 12. Considerable adjusting of the copper sulphate content was required so that the development of the proper shade of green would coincide with the bleaching of the red areas to the desired degree.

Strawberries

In the preserving of strawberries the fixing period was shortened as much as possible because of the rapid darkening of the fruit. However, if the fixing solution was poured off too soon and the holding solution added, the color became mottled due to insufficient fixing of the red pigments. The coloration was nearly identical in all varieties preserved and the following procedure was used for all:

Fixing solution No. 6 was used, followed by holding solution No. 11 after 1 to 3 hours. Over-darkened specimens were brightened somewhat by the addition of small quantities of sulphurous acid to the holding solution after 3 or 4 days.

Leaves

In some cases when the copper sulphate content of the fixing solution was high, leaves were fixed satisfactorily along with the fruit. However as they often took on a dull brown color, it was found more satisfactory in many cases to preserve the leaves separately, by immersing 2 days in fixing solution No. 3. They were then removed and mounted with the fruit in the final holding solution.

Conclusion

For the successful preservation of fruits careful observation and technic were as important as the proportions of the solutions. Although the preserved fruits lacked certain life-like qualities of living material, form and color were retained well enough to make the specimens valuable for exhibition and reference purposes.

Preserving Solutions

The formulae in the following list were selected as being the most valuable ones originated by Vacha, Mackenzie and the writer.

Fixing solutions:—

No. 1. Shaded red and yellow plums:—Formaldehyde 40 cc, sulphurous acid 4 cc, copper sulphate 50 gms, sodium chloride 350 gms,

water 5600 cc. This solution has a specific gravity of approximately 1.050 (nearly that of plums) and will require only 5 to 15 cc of glycerine per 100 cc of solution to balance.

No. 2. Dark red plums:—Formaldehyde 8 cc, sodium chloride 50 gms, copper sulphate 10 gms, water 1000 cc.

No. 3. Vacha's fixing solution:—Fresh sulphurous acid 142 cc, ethyl alcohol 142 cc, formaldehyde 3 cc, oil of cloves 1 cc, copper sulphate 1 gm, acetyl-salicylic acid 1.5 gms, water sufficient quantity to make 1000 cc. In making up this solution, dissolve the oil of cloves in the alcohol. When this is added to the rest of the solution a white emulsion is formed which takes 48 hours or more to clear.

No. 4. Mackenzie's solution for hard green pears:—Water 3785 cc (1 gallon), sulphurous acid 28.4 cc (1 ounce), copper sulphate 85 gms.

No. 5. Mackenzie's solution for pears with russet and blush:—Water 3785 cc (1 gallon), sulphurous acid 21.3 cc (¾ ounce), formaldehyde 7.1 cc (¼ ounce), sodium chloride 14.2 cc (½ ounce), copper sulphate to suit specimen.

No. 6. Strawberries:—Water 200 cc, ethyl alcohol 20 cc, formaldehyde 8 cc, sulphurous acid 10 cc, oil of cloves 1 cc, copper sulphate 3 gms. Dissolve the oil of cloves in the alcohol. The emulsion which will result when this is mixed in the water solution will clear after 48 hours or more.

No. 7. Mackenzie's solution for green or yellow apples:—Paraffin oil 3785 cc (1 gallon), formaldehyde 56.8 cc (2 ounces).

No. 7a. Mackenzie's solution for red apples:—Paraffin oil 3785 cc (1 gallon), formaldehyde 28.4 cc (1 ounce).

Holding solutions:—

No. 8. Mackenzie's holding solution for plums:—Water 3785 cc (1 gallon), sulphurous acid 28.4 cc (1 ounce), ethyl alcohol 42.6 cc (1½ ounces).

No. 9. Mackenzie's holding solution for pears:—Water 3785 cc (1 gallon), sulphurous acid 28.4 cc (1 ounce).

No. 10. Vacha's holding solution:—Same as solution No. 3, omitting the copper sulphate.

No. 11. Holding solution for strawberries:—Water 1000 cc, formaldehyde 2 cc, ethyl alcohol 10 cc, oil of cloves 2 cc, sulphurous acid 25 cc.

No. 12. Mackenzie's solution for bleaching apples:—Water 3785 cc (1 gallon), sulphurous acid 56.8 cc (2 ounces).

No. 13. Mackenzie's holding solution for apples:—Water 3785 cc (1 gallon), sulphurous acid 28.4 cc (1 ounce).

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2. Peterson, M. Formulae for preserving fruits and vegetables. Mimeo. Circ. University of Minnesota, St. Paul, Minn. 1918.
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On the Bearing Behavior of the Fuerte Avocado Variety in Southern California

By R. W. Hodgson and S. H. Cameron, *University of California, Los Angeles, Calif.*

Introductory

Fuerte,[1] the principal avocado variety grown in southern California, is satisfactory in all respects except bearing behavior. During the past 15 years it has exhibited a decidedly erratic bearing habit and the conclusion is now general that unless practicable means can be devised for regulating its production this variety will have to be discarded. As an indication of its behavior may be cited the sequence of crops harvested during the past 7 years, 1928–29 to 1934–35, namely, medium, small, large, medium, small, small, and large respectively. It will be observed that this period included three small crops, two medium crops, and two large crops, and that 4 years elapsed between the latter. This paper comprises the first report on a study of the bearing behavior of this variety.

The orchard used in this study is situated in the La Habra Heights district of Los Angeles County, which is an important center of avocado production. It has received good care and is above average for the locality. Frost protection has not been considered necessary and no tree injury has occurred during the past decade. In January, 1932, the temperature in an adjoining orange orchard dropped to 25 degrees F for a short period one night, which caused injury to young trees. The avocado trees showed little evidence of injury, however, though the succeeding crop was produced mainly in the tops of the trees, with the exception of those at the upper end of the orchard which rises rather abruptly. In this area the trees are much smaller than in the lower and relatively flat bottom which comprises the bulk of the planting. The orchard was originally a double planting of the Fuerte and Puebla varieties but in recent years many trees of the latter, and a few of the former, have been removed because of crowding which resulted from too close planting. The trees were planted as seedlings in the spring of 1921 and were budded or topworked during the growing seasons of 1922 and 1923.

Data and Discussion

The data here summarized and discussed consist of the annual yield records, in number of fruits, of each of 128 trees for the 6-year period, 1928–29 to 1933–34 inclusive. The yields for each tree were plotted and a study of the graphs indicated that with the exception of seven trees, six of which fail to correspond only in the first or last year of the 6-year period, they fall into four groups of similar behavior.

[1]For the history and characteristics of this variety see the following references:

Popenoe, W. Manual of tropical and subtropical fruits. 9–78. The Macmillan Company, New York. 1920.

Ryerson, K. A. Avocado culture in California. Part I, History, Culture, Varieties, and Marketing. Calif. Agr. Exp. Sta. Bul. 365. 1923.

Since it is not practicable to reproduce all the graphs here the average yields in each of the four groups, including the exceptions noted, have been determined and are shown graphically in Fig. 2. The mean temperatures for certain months during the 7-year period, 1927–28 to 1933–34, at the nearest official Weather Bureau station, Yorba Linda, about 10 miles distant, are shown in Fig. 1. In the following paragraphs the crop sequences and relationships for each of the four groups are summarized and briefly discussed.

Group 1 (69 trees):—Crop sequence—medium, small, large, medium, small, and small. The general similarity between the graph portraying the bearing behavior of this group representing more than half of the trees, and those depicting the mean temperatures of the preceding February and March suggests a causal relationship, particularly in view of the fact that these months normally represent the peak of the blooming period of the Fuerte variety. It will be observed that the correspondence is perfect with two exceptions, 1931–32 and 1933–34. In the former a medium crop followed a large crop even though temperature conditions were favorable during the blooming period; this suggests that the large crop of 1930–31 was the dominant factor determining the amount of crop in 1931–32. In the latter (1933–34) the situation was reversed. Some crop increase followed a small crop although temperature conditions were even less favorable; this suggests that the small crop of 1932–33 permitted an increase in the succeeding crop in spite of unfavorable weather during the blooming period.

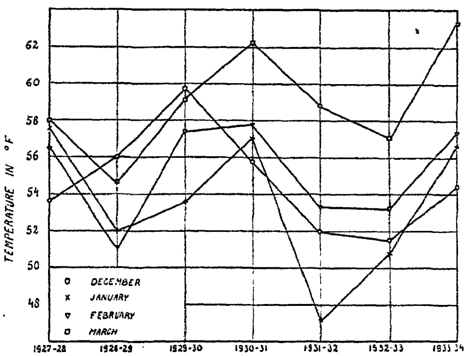

FIG. 1. Mean monthly temperatures at Yorba Linda, Orange County, Calif.

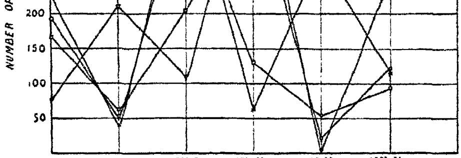

FIG. 2. Average yields of Fuerte avocado trees, plotted by groups of similar bearing behavior.

It is interesting to note that during the 7-year period covered by the temperature graphs there were three winters, namely, 1929–30, 1930–31, and 1933–34, too warm to properly break the rest of cer-

tain temperate-zone fruit trees, and each was followed by the occurrence of the phenomenon known as delayed foliation (1). Two of these winters, both in odd-numbered years, preceded large crops of the Fuerte avocado; in each case the large crop followed a small crop. The third (1930–31), as noted above, preceded a medium crop which in turn followed a large crop.

Group 2 (22 trees):—Crop sequence—medium, small, large, small, good, and small. The trees in this group alternated regularly in bearing behavior throughout the period in question, starting like those in group 1 but ending in exactly the opposite phase. It will be observed that they started higher than any other group and were likewise higher in 1930–31, following the first of the two successive mild winters; also that they dropped considerably lower in 1931–32 than group 1. Most of the trees in group 2 are situated in the upper end of the orchard where, as previously mentioned, they average much smaller in size. It seems reasonable to assume, therefore, that their first large crop, which followed the mild winter of 1929–30, actually represented a much heavier production per unit of tree volume than occurred the same season on the larger trees in the bottom area, and that this was responsible for the small crop the next season even though it followed another mild winter. Having produced a small crop that season, 1931–32, they were able to bear a good crop the following season, 1932–33, and did so because of their favorable hillside location in spite of the generally unfavorable winter of 1931–32. Further evidence supporting this conclusion is afforded by the fact that 18 of 20 younger trees of the same variety located higher up on a nearby hillside behaved similarly during the period, 1930–31 to 1933–34 inclusive.

Group 3 (12 trees):—Crop sequence—small, medium, small, very large, very small, and good. This group also alternated throughout the full period but started in a phase opposite to that of groups 1 and 2. The one large crop it produced followed the second of the two successive mild winters; its two other on-crop phases corresponded with unfavorable winters which depressed these crops markedly. It is interesting to observe that following the medium crop of 1929–30, which was the result of the unfavorable preceding winter, this group did not drop so low in 1930–31, following the first of the two successive mild winters. Apparently this permitted it the next year, the mildest of the period, to reach the highest maximum attained by any group. It should be noted, however, that this maximum was in turn followed by the smallest crop of any group. This was evidently the result of the combined effects of an unusually large crop and very unfavorable temperature conditions during the blooming period. It will also be observed that following this lowest minimum the succeeding crop was good notwithstanding the fact that temperature conditions in 1932–33 were even less favorable than in 1931–32. One of the 20 younger trees above-mentioned has followed the behavior of this group.

Group 4 (25 trees):—Crop sequence—medium, small, medium, large, very small, and small. During the first 2 years the behavior of this group was similar to that of groups 1 and 2 excepting that in

1928–29 the average yield was somewhat lower and in 1929–30 somewhat higher than for the other two groups. This may explain the fact that in 1930–31 a medium crop was produced whereas groups 1 and 2 yielded large crops. Having borne only a medium crop following the first of the two successive mild winters this group was able to produce a large crop in the second and more favorable season. In this connection attention is directed to the contrasting behavior in these 2 years, 1930–31 and 1931–32, between groups 3 and 4. In the first year, group 3 produced a considerably smaller crop than group 4; this apparently enabled it to bear a correspondingly larger crop the second year. Study of the graphs shows that this relation obtains for all the groups. From 1931–32 on, group 4 behaved like group 3 except that because of the somewhat smaller crop that season the yield the following year did not drop quite so low nor did it rise so high in 1933–34.

A study of the graphs of these four groups shows that large crops were produced only in seasons which followed mild winters and that they invariably succeeded small or medium crops. It also indicates that large crops were followed by small or medium crops even though temperature conditions during the blooming period were apparently favorable.

Conclusions

It is believed that these data support the following conclusions: (1) In southern California the Fuerte avocado variety exhibits a pronounced tendency to the alternate bearing habit, the causal factor for which is the amount of crop produced the previous season; (2) temperature conditions during the blooming period comprise an important factor in the bearing behavior of this variety; and (3) the crop produced in any given season is determined by the percentage of trees in the on-crop phase and temperature conditions during the period of bloom.

Acknowledgments

Appreciation is expressed to P. J. Weisel and his Superintendent, R. H. Marsh, for the yield data employed in this study.

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Total Nitrogen in Developing Flowers and Young Fruits of the Valencia Orange

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NOTWITHSTANDING the fact that flowering and fruit-setting are generally believed to constitute a severe drain on the reserve food materials of fruit plants there is surprisingly little information in horticultural literature regarding the magnitude of the losses involved. Since the blossom parts and most of the young fruits are normally shed, a determination of their composition should give some indication of these losses. We have attempted to ascertain the loss from a Valencia orange tree by determining the total nitrogen content of the developing flowers and young fruits.

Materials and Methods

Flowers and young fruits were collected from four 12-year-old Valencia orange trees, at weekly or bi-weekly intervals from March 6 to June 24, as indicated in the accompanying table. Collections were begun when small buds appeared and were continued until the young fruits were almost large enough to permit the separation of the pulp and rind, about 2 cms in diameter. Studies of changes in composition of the developing fruit from this stage to maturity are now in progress. The number of individual flowers and fruits collected for each sample varied from 20 to over 200—averaging about 40. Because of the similarity of results on comparable samples from the different trees we believe that our samples were representative.

Blossom buds collected in March were too small to be divided into constituent parts. Beginning with the collection of April 1 the blossoms were subdivided into petals, pistil, and stamens. By April 15 most of the flowers were fully open; petals and stamens either had shed or were about to fall. Preceding blossom drop, the "pistil" fraction included stigma, style and ovary, after blossom drop, the ovary only was included. Segregations of flowers of different sizes and stages of maturity and later young fruits of different size were made at each collection.

The collected material was dried, ground if necessary, and total nitrogen determined by the Kjeldahl-Gunning method.

Data and Discussion

The data relating to comparable fractions from the four trees were so nearly identical that average values are presented in Table I and Fig. 1. They indicate a gradual increase in dry weight and in absolute nitrogen content of blossoms and young fruits during March and April and a very rapid increase during May and June. Calculated as a percentage of the dry weight the nitrogen content shows a slight but consistent decrease during the whole period. Howlett (2) reports similar trends in apple blossoms and young fruits. It is of interest to note that the values for nitrogen calculated on the dry weight basis are

almost identical for apple and orange blossoms but that orange blossoms contain from 50 to 100 per cent more dry matter and nitrogen on the absolute basis than apple blossoms.

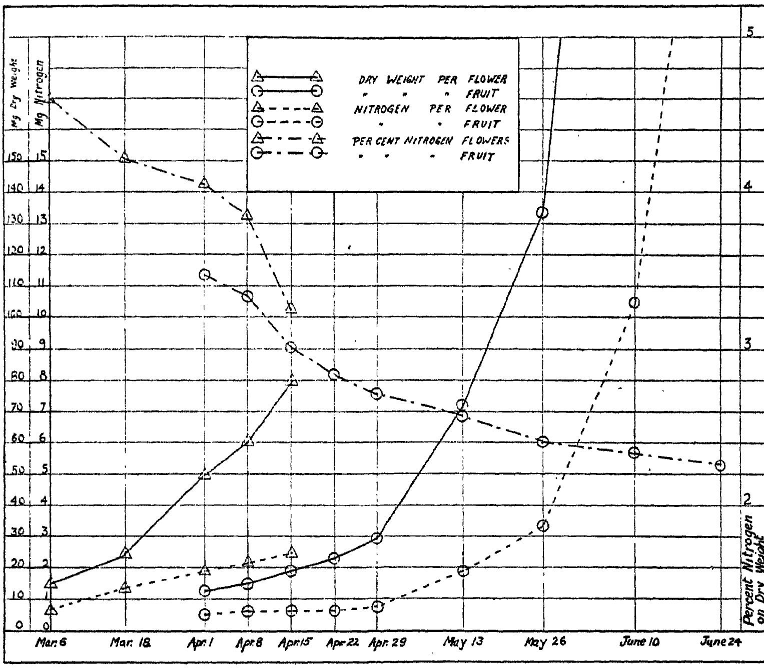

FIG 1. Dry matter and nitrogen content of flowers and young fruits of the Valencia orange.

Considering the relative distribution of nitrogen and dry matter in the flower parts, it will be seen that in mature orange flowers the petals contain nearly 45 per cent of the nitrogen and almost as much of the dry weight, the stamens about 30 per cent and the pistil about 25 per cent of both nitrogen and dry matter. These results differ from those reported by Howlett (2) for apple blossoms. He states that at full bloom the petals comprised at least ¼ to ⅓ of the total dry matter of the entire flower and contained ⅙ or less of the total nitrogen.

Our data are not extensive enough to permit calculation of the actual amount of nitrogen lost to the tree as a result of the shedding of blossoms and young fruits. There is of course the possibility of a return of part of this nitrogen to the tree prior to abscission of these organs. On this point our data are not conclusive. The return, if any, appears to be insignificant. Evidence which tends to support the conclusion that blossoming, and shedding of young fruits results in an actual diminution in the nitrogen content of the tree as a whole has been presented in a previous paper (1). We reported that fallen

TABLE I—Dry Weight and Nitrogen Content of Flowers and Young Fruits of Valencia Orange. Average Values for Material Collected from Four Trees

Date of Collection	Approximate Size and Stage of Maturity	Dry Weight per Flower (Mgs)				N on Dry Weight Basis (Per cent)				Nitrogen per Flower (Mgs)			
		Whole	Petals	Pistil	Stamens	Whole	Petals	Pistil	Stamens	Whole	Petals	Pistil	Stamens
	Flowers												
Mar. 6...	Green buds 1–2 mm diam.	15.0	Not separated			4.60	Not separated			0.69	Not separated		
Mar. 18..	Showing white 2–4 mm diam.	24.2	Not separated			4.21	Not separated			1.27	Not separated		
Apr. 1...	White tips, 5 x 8 mm	49.8	19.2	11.5	19.1	4.05	3.97	3.67	4.80	1.91	0.71	0.53	0.67
Apr. 8...	Full size, closed 8 x 16 mm	60.1	23.5	15.0	21.6	3.85	3.81	3.34	4.43	2.13	.85	.62	.66
	Full open	74.7	31.8	16.7	26.2	3.68	3.75	3.40	4.27	2.78	1.19	.71	.88
Apr. 15..	Mature, petals ready to drop	79.9	35.6	19.0	25.3	3.25	2.96	3.10	3.54	2.47	1.10	.65	.72
	Young Fruits												
Apr. 22..	35 mm diam.	—	—	23.0	—	—	—	2.84	—	—	—	.65	—
Apr. 29..	50 mm diam.	—	—	29.4	—	—	—	2.72	—	—	—	.78	—
May 13..	60 mm diam.	—	—	70.2	—	—	—	2.58	—	—	—	1.90	—
May 26..	70 mm diam.	—	—	133.8	—	—	—	2.41	—	—	—	3.36	—
June 10..	100 mm diam.	—	—	428.0	—	—	—	2.34	—	—	—	10.51	—
June 24..	200 mm diam.	—	—	1587.0	—	—	—	2.26	—	—	—	34.50	—

flower parts collected under a 12-year-old tree contained approximately 30 grams of nitrogen. In addition to this we must take into account the nitrogen lost in young fruits during the "June drop". This probably is greater in absolute amount than that contained in the blossom parts. Such a calculation while of interest would not be of general application because of the fact that the amount of bloom produced by orange trees varies so greatly from season to season and district to district. Seasons of heavy bloom are usually those of heavy "June drop" and light crop. Trees in the hot interior sections of California bloom much more profusely than they do in the cooler regions near the coast. In general, however, they mature smaller crops than trees in the coastal districts. Such observations indicate that size of crop is inversely proportional to amount of bloom and suggest that some factor associated with blossoming and fruit setting determines the amount of fruit which the tree matures.

It seems reasonable to suggest that the determining factor is the supply of nitrogen. In Table II are presented data relating to flowers of approximately equal dry weight collected from the same tree on March 1, 8, and 15. Examination of these data shows that flowers which develop early in the blooming period (March 1) are richer in nitrogen than those which develop later (March 15). These results, together with those previously reported (1), indicating a minimum nitrogen content in the tree in May, suggest that profuse blossoming and growth of young fruits may so reduce the nitrogen supply that the amount becomes a limiting factor which determines the amount of fruit the tree can retain during this period. This may explain the observed fact that the first fruits set are much more likely to mature than those set later.

TABLE II—NITROGEN CONTENT OF FLOWERS OF SIMILAR DRY WEIGHT COLLECTED FROM THE SAME TREE ON DIFFERENT DATES

Date of Collection	Dry Weight per Flower (Mg)	Nitrogen Dry Weight Basis (Per cent)	Nitrogen per Flower (Mg)
March 1	44.8	4.45	0.020
March 15	42.4	3.41	.014
March 8	58.4	4.01	.023
March 15	58.0	3.28	.019
March 8	62.3	3.52	.022
March 15	64.1	3.30	.021
March 8	75.4	3.64	.027
March 15	77.5	3.13	.024

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Spraying Apples for the Prevention of Fruit Set

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Introduction

EXPERIMENTS begun in 1933 (1) to determine whether or not certain chemicals applied to apple trees just before the petals of the blossoms opened would destroy the blossom buds without seriously or permanently injuring other parts such as leaves and fruit spurs were carried on during 1934 in Arkansas, Missouri, Indiana, Georgia, North Carolina, and Virginia.

The sprays were applied and results were recorded at Fayetteville, Arkansas, by John C. Dunegan, using trees furnished by the University of Arkansas; at Mountain Grove, Missouri, by M. A. Smith, using trees furnished by the Missouri Fruit Experiment Station; at Vincennes, Indiana, by Leslie Pierce, using trees furnished by Knox County; at Cornelia, Georgia, by Lee M. Hutchins and C. H. Alden, using trees furnished by the Georgia State Board of Entomology; at Raleigh, North Carolina, by Ivan D. Jones, using trees furnished by the North Carolina Agricultural Experiment Station, and at Arlington Farm, Virginia, by E. L. Green and M. C. Goldsworthy.

As in 1933 there were variations in the results from the different regions, apparently caused by differences in weather conditions, in tree vigor, and in the stage at which the sprays were applied. It will be noticed, however, that results from the use of cresylic acid and tar oil distillate were rather consistent in all of the experiments. Varietal differences seemed to be unimportant.

Plan of Experiments

The plan of the 1934 experiments was similar to that of 1933 (1), except that, to avoid excessive foliage injury, applications were made earlier in most cases and some chemicals notably lime-sulphur solution were replaced by others that were considered more promising. The varieties of apples used were: In Arkansas, Stayman Winesap, Ben Davis, and Winesap; in Missouri, Champion; in Indiana, Grimes; in Georgia, Arkansas Black; in North Carolina, Starking and Rome; in Virginia, numerous varieties including Paragon, Arkansas Black, Grimes, Delicious, York Imperial, Winesap, and Jonathan. In all cases the sprays were applied with power outfits developing 250 to 300 pounds pressure. In some cases only half the tree was sprayed, the other half being held as a check; in all other cases the entire trees were sprayed, with adjacent trees of the same age and variety held as checks. Most of the trees were sprayed in the cluster-bud stage but some were in full bloom.

The sprays were sodium polysulphide, 1 pound to 5 gallons; copper sulphate, 4 to 5 pounds to 50 gallons; sodium nitrate, 10 pounds to 50 gallons (6 to 50 in Missouri); ferrous sulphate 4 to 6 pounds to 50 gallons; sodium hyposulphite, 10 pounds to 50 gallons; oil emulsion 2½ to 3 per cent; cresylic acid 3 to 10 per cent; tar oil distillate, 3 per cent. Most of these were used because they had given some

promise in the preliminary experiments previously reported (1). Sodium hyposulphite was used at the suggestion of M. A. Smith, of this Bureau, and cresylic acid at the suggestion of J. M. Ginsburg, of the New Jersey Agricultural Experiment Station. Differences in dilutions of individual sprays will not be mentioned except where they appear to have affected results. The tar oil distillates used were of the type commonly called coal-tar creosotes and which are supposed to have a distillation range of between 225 and 400 degrees C.

Results of Experiments

Sodium polysulphide:—Sodium polysulphide was used in Missouri only. Applied at late cluster-bud stage it reduced fruit set only 50 per cent and caused severe foliage injury. There was no injury to spurs or twigs. New leaves soon appeared that remained uninjured.

Sodium hyposulphite:—Sodium hyposulphite was used in Missouri only. Applied at late cluster-bud stage fruit set was reduced 75 per cent with but slight foliage injury. There was no injury to spurs or twigs.

Copper sulphate:—Copper sulphate applied to Stayman Winesap trees at late cluster-bud stage in Arkansas killed 75 per cent of the blossoms and severely russeted the fruit that set. There was slight foliage injury, the opening leaves being curled, but no injury to spurs or twigs. In Missouri, at the late cluster-bud stage, the crop was reduced only 25 per cent with slight foliage injury and no injury to spurs or twigs. In Indiana an application at full bloom reduced fruit set only 50 per cent and only slightly injured the foliage. Spurs were not injured. In Georgia, applied in late cluster-bud stage, copper sulphate was effective in preventing fruit set, but killed many leaves and an occasional spur. In North Carolina, applied to Starking trees at late cluster-bud stage, it reduced fruit set 95 per cent but caused severe foliage injury and killed occasional spurs. In Virginia, applied to several varieties in early to late cluster-bud stages, it reduced fruit set 50 per cent, and severely russeted the fruit that set. Foliage injury was severe and an occasional fruit spur was killed. In all the different regions the trees recovered quickly from the copper sulphate treatment and appear to have set a good crop of fruit buds.

Sodium nitrate:—Sodium nitrate applied to Stayman Winesap trees at late cluster-bud stage in Arkansas reduced fruit set only about 10 per cent and caused only slight foliage injury. There was no injury to spurs or twigs and growth was not interfered with. Applied to half a Ben Davis tree in full bloom it destroyed the leaves and the effects were noticeable throughout the season. Since the control half of the tree set no fruit, results on fruit set could not be taken. When used at the rate of 6 pounds to 50 gallons in Missouri at late cluster-bud stage, fruit set was not materially reduced and there was only slight foliage injury. Twenty-five per cent of the fruit was russeted. In Indiana, the blossoms, sprayed in full bloom, were all killed. Foliage injury was severe and an occasional spur was killed. In Georgia, applied at late cluster-bud, sodium nitrate reduced fruit set somewhat and caused some leaf and spur injury. In North Carolina, applied to Starking at late cluster-bud, it reduced the crop 95 per cent with only

slight foliage injury and no spur injury. In Virginia, applied at early to late cluster-bud stage on several varieties, it reduced the set only slightly and caused only slight leaf injury and no spur injury. In all the different regions the trees recovered quickly from the treatment and the indications at this time are that all trees have formed fruit buds for next year except one Ben Davis tree in Arkansas.

Ferrous sulphate:—Ferrous sulphate applied to Stayman Winesap trees at the late cluster-bud stage in Arkansas reduced fruit set 80 per cent without serious injury to foliage. Neither spurs nor twigs were injured but the fruit was severely russeted. Growth was apparently not checked. In Missouri when applied in late cluster-bud stage, it reduced the crop only 15 per cent with no spur or twig injury, and only slight foliage injury. Twenty-five per cent of the fruit was russeted. In Georgia, an application at late cluster-bud stage apparently killed all blossom buds and caused severe foliage injury. In Virginia, applied to varieties in early to late cluster-bud stage it reduced the set only 25 per cent, but was more effective in the late cluster-bud stage. All the fruits that set were badly russeted. There was slight leaf injury but no spur or twig injury. The injury caused by ferrous sulphate was not serious in any of the different regions except Georgia. In that state the fact that the tree used was low in vigor may explain the severe injury.

Oil emulsion:—Oil emulsion applied to Winesap trees at early cluster-bud stage in Arkansas reduced fruit set 45 per cent and russeted the fruit that set. Foliage injury was not serious. Spurs and twigs were not injured. Subsequent growth was normal. In Missouri, a 4 per cent emulsion applied at late cluster-bud stage, reduced the set 90 per cent, destroyed 90 per cent of the leaves and killed 20 per cent of the fruit spurs. Fruit spur injury was not apparent until June. In Georgia, neither the sprayed tree nor the check set sufficient fruit to give results. There was little injury to leaves and spurs. In North Carolina, applied to Starking at late cluster-bud stage, it reduced fruit set 95 per cent, and caused severe spur and foliage injury. In Virginia, whether applied at early or late cluster-bud and regardless of the variety of apple used, a 2½ per cent dilution did not materially reduce the crop, caused only slight foliage injury and did not injure spurs or twigs. It retarded blooming somewhat but only for a day or two.

Cresylic acid:—Cresylic acid used alone or in combination and at all dilutions, ½ per cent to 10 per cent, reduced fruit set practically 100 per cent in all the regions in which it was used. Injury to foliage was usually apparent within 15 minutes. In Arkansas, a 10 per cent dilution applied to Winesap in early cluster-bud, killed all blossom-buds, leaf buds and fruit spurs. In Missouri, a 3 per cent dilution applied at late cluster-bud stage, killed all blossom buds, all opening leaves, and 35 per cent of the fruit spurs. In Georgia, a dilution of 3 per cent killed practically all blossoms and all opening leaves. Some spurs were injured but there appears to be a good set of blossom buds for 1935. In North Carolina, a ½ per cent dilution combined with a 3 per cent tar oil distillate applied to Rome at late cluster-bud killed all blossoms and leaves. It retarded growth somewhat and caused

some spur injury. In Virginia, a 5 per cent dilution applied to assorted varieties at either early or late cluster-bud killed all blossom buds, all opening leaves, and 90 to 100 per cent of the fruit spurs with considerable injury to stems.

Tar oil distillate:—Tar oil distillate applied in Indiana at full bloom stage killed all blossoms, caused severe foliage injury, and killed an occasional fruit spur. New foliage developed quickly following the injury. In Georgia, applied at late cluster-bud stage, it killed 99 per cent of the blossoms and many leaves. Spurs and twigs were not injured. Recovery was rapid with apparently a good set of fruit buds for 1935. In North Carolina, applied at late cluster-bud stage, it killed all blossoms directly hit and caused only slight foliage injury. Spurs were not injured. In Virginia it caused only slight foliage injury and killed only an occasional spur. When applied at the late cluster-bud stage it killed practically all blossom buds. When applied at early cluster-bud stage it killed the more advanced flower buds but some of the more backward ones escaped. The trees have apparently set a good crop of blossom buds for 1935.

Effects of the 1933 Treatments on 1934 Blossom Set

In 1934, in Arkansas, there were practically no blossoms on either the treated or untreated halves of the trees used in the 1933 experiment. In Missouri, trees sprayed during full bloom in 1933 with copper sulphate, sodium nitrate, and sodium polysulphide resulting in blossom removal and severe foliage injury, produced new foliage rather quickly, fruit buds were formed, and good crops were produced in 1934 except on the trees sprayed with sodium polysulphide. In Indiana, the tree sprayed in full bloom with copper sulphate and the one sprayed with sodium nitrate in 1933 bloomed well in 1934; the one sprayed with lime-sulphur solution had little bloom in 1934, probably because the lime-sulphur did not reduce the set of fruit in 1933. In Georgia, spur and twig injury from copper sulphate was still apparent but both treated and untreated trees of all plots set too light a crop in 1934 to draw conclusions on the effect of the 1933 treatments. In North Carolina, the trees used in 1933 were killed by fire.

Conclusions

Although, as in 1933, all of the sprays caused some foliage injury, still certain ones appear promising in that fruit set was prevented with practically no spur injury and the indications are that fruit buds have been formed for next year.

None of the inorganic materials, (sodium polysulphide, copper sulphate, sodium nitrate, ferrous sulphate, sodium hyposulphite), applied at the cluster-bud stage and at the strengths used can be depended upon to prevent fruit set under all conditions, and the fruits that do set are liable to be severely russeted.

The oil emulsions commonly used as dormant sprays have not consistently destroyed the blossoms when applied at cluster-bud stages.

Cresylic acid consistently killed practically all blossom clusters but caused severe injury to foliage, spurs, and twigs. It deserves further trials at weaker dilutions.

Of the materials used in 1934, tar oil distillate proved to be the most satisfactory for accomplishing the desired results. When applied at the late cluster-bud stage it killed practically all the blossoms, and caused leaf injury but practically no injury to spurs and twigs. New foliage developed rapidly and fruit buds appear to be formed for 1935.

Additional experiments using various concentrations of the most promising materials at different stages of blossom development will be continued in 1935.

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Metaxenia Studies with Apples

By E. S. Degman, and E. C. Auchter, *U. S. Department of Agriculture, Washington, D. C.*

THE term "Metaxenia" is relatively new, having been coined recently by Swingle (31). His definition of metaxenia is "The direct effect of the pollen on the parts of the seed and fruit lying outside the embryo and endosperm." However, the possibility of the pollen affecting parts of the seed and fruit lying outside the embryo and endosperm has been considered and discussed by investigators for many years.

At first the question was: Does the pollen have an influence on tissue lying outside the embryo and endosperm? Now the question is: In what plants does pollen have such an effect and to what extent?

A brief review of some of the literature pertaining to this subject is presented. Garfield (9) is quoted as having obtained changes in the color, shape and flavor of the fruit, in crosses of Wagener and Tolman Sweet apples. Munson (19) cited several cases of flower and vegetable crosses, some of which showed an affect of the pollen while others did not. In his own experiments with tomatoes and eggplant he found no direct effect of pollen. Waite (34) reported that with several varieties of pears, selfed fruits were narrower and smaller than crossed fruits. With most of the varieties which he studied, fruits obtained from crosses (other than selfed crosses) were similar in size and shape regardless of which variety was used as the pollen parent. However, with the Bartlett variety fruits resulting from the cross Bartlett by Easter were larger than fruits from any other cross with Bartlett as the female parent. In view of the work of Tufts and Hansen (33), it seems probable that the differences in shape of pears noted by Waite were caused by the differences in the number of seeds in his selfed and cross-pollinated fruits. Close (3) reported differences in shape and color of fruits of crosses of some early varieties of apples as compared to open pollinated fruits. Lewis and Vincent (18) reported that the color of Spitzenburg apples was influenced by the pollen parent, pollen of red varieties, resulting in fruit darker red in color than pollen of the Yellow Newtown. Working at the same station, Kraus (16) concluded from "hundreds of crosses made" that pollen did not influence the color of the resulting fruit. Kraus stated further that if the pollen could influence the color it would have to be through a stimulating agent transmitted from the seed to the stomatic tissue.

Hume (13) found that the presence of seeds in the Japanese persimmon caused dark flesh, less astringency and early maturity as compared to fruits containing no seeds, and that the amount of darkening, the degree of change in astringency and time of ripening was proportional to the number of seeds. Whether or not this should be considered an example of metaxenia is problematical. Noguchi (27) also working with the Japanese persimmon found that pollen of pointed varieties caused rounded varieties to be more pointed and that pollen of astringent varieties caused the fruits of sweet varieties to be more astringent. He attributes these changes to metaxenia.

Returning to the apple, Crow (5) pollinated Wealthy with McIntosh and Wagener. Fruit of larger diameter was produced when McIntosh pollen was used even though there were fewer seeds per apple than where Wagener pollen was used. If the leaf area and other factors were the same in each case, it is possible that this was a metaxenic effect. Heinicke (11) found that when the weight of the spur was constant, the weight of the apple was proportionate to the number of seeds. It is probable that not only the number of seeds per fruit, as affecting size, shape, color, etc., must be given consideration in studying the possibility of metaxenia but also the vigor of spurs, number of leaves per fruit, etc. Alderman (1) reported a correlation between weight of apple and number of seeds when the apples were grouped according to pollen parent but not much correlation with individual fruits. Crandall (4) also reported a correlation between fruit weight and number of seeds. Wicks (35) reported that a number of cross pollinations with apples made over a 3-year period showed no effect of pollen on size, shape, color or quality of the resulting fruit. Zederbaur (37) working with apples reported that size and shape of the pollen parent were transmitted to the fruit of the immediate cross.

Popenoe (28) cited the finding of Bruce Drummond with the date palm. Drummond is reported to have found that "A difference of as much as one-third in the size, and of twenty days in the time of ripening seems to have been due to a change in the male used for pollinating." Nixon (24) also refers to this reference by Popenoe of Drummond's experiments. In 1926 the question of the influence of the pollen parent on the stomatic tissue received special emphasis when Swingle (31, 32) reported on pollination work, conducted in 1924 and 1925, with the date palm and suggested that the term "metaxenia" be used to describe the "direct effect of the pollen on the parts of the seed and fruit lying outside the embryo and endosperm." Though other descriptive terms have been suggested by other investigators, the term "metaxenia" is now in general use. Since the phenomenon of metaxenia could not be explained on a morphological basis, Swingle (31) suggested a hormone theory to explain it.

Nixon (24, 25, 26) has reported further on these metaxenia studies in dates and has shown the possibility of a commercial application of metaxenia. He found pollen to influence size and time of ripening but not to influence quality. As reviewed by Nebel (20), Roh (29) working with apples reported that "Differences due to the influence of pollen pertain not only to the size, shape, and color of the fruit, but also to the specific gravity of the flesh of the fruit, its chemical composition and keeping qualities". Einset (7) found a correlation in apples between weight of fruit and number of seeds. Nebel (20) crossed Fameuse with McIntosh and Yellow Bellflower. He found the apples pollinated with McIntosh to be more uniform and to have slightly more color than the apples pollinated with Yellow Bellflower. Other characters differed but to a less extent. Yasuda and Kitamura (36) reported finding metaxenia in three species of Solanum. Kostoff (15) questioned Swingle's hormone theory and suggested that the foreign material (embryo and endosperm) might cause a thickening

of the protoplasm in their immediate vicinity, and that this thickening of the protoplasm might cause more rapid cell division and thus result in greater growth. His theory does not allow for a thinning of the protoplasm and consequently would not explain a reduction in size of the fruit. Kobel (14) did not find metaxenia in crosses of sweet and sour cherries. Evreinoff (8) apparently found metaxenia in some peach and pear crosses but did not give any data. Harrison (10) found metaxenia in cotton. The pollen parents influenced time of maturity, length of lint, and fuzziness of seed. Interspecies crosses acted similar to intervariety crosses. Nebel and Trump (22) found metaxenia in McIntosh when pollen of Red Astrachan and Yellow Bellflower were used. Metaxenia was present in weight of apple, diameter of apple, pH of juice and titratable acidity. The Red Astrachan crosses appeared of better quality. Nebel (21) reported no correlation between weight of apple and number of seeds. He used individual apples. Krumbholz (17) reported that Baumanns Reinette pollen gave consistently heavier fruits of the apple than pollen of Kaiser Alexander. With large leaf area per fruit he did not find the differences in weight. Hibbard (12) found metaxenia in crosses of Ingram by Ben Davis and Wealthy. The first year the fruits pollinated with Ben Davis pollen had more seeds than the fruits pollinated with Wealthy pollen, while in the second year this condition was reversed. Yet both years the fruits produced by Ben Davis pollen were significantly heavier.

Tufts and Hansen (33) reported results with pear crosses similar to those reported by Waite (34). They found thickness of pears near the calyx end to be correlated with seed number. They seemed to doubt that the differences in shape of pears should be considered metaxenia. Nebel and Kertesz (23) found significant differences in acidity and in some cases total sugars in McIntosh apples resulting from different pollens. They thought that general characters were more apt to be transmitted than specific characters.

1933 Investigations

A study of metaxenia in apples was begun in 1933 by the U. S. Department of Agriculture, in western Maryland. A large number of cross pollinations were made on several of the leading varieties. A severe rosy apple aphis infestation so affected the normal functioning of the leaves and injured the fruits so badly in the case of most varieties that definite conclusions were not attempted. It was noted at harvest time that wherever two fruits had been allowed to develop on the same spur that the individual fruits were much more oblate in shape than where only one fruit per spur had been allowed to develop. This was especially noticeable in the York Imperial fruits developed from different crosses. Both the cavities and basins were shallower. Care was taken in 1934 to remove all but one fruit per spur in the different crosses.

1934 Investigations

The work was continued in 1934 using Summer Rambo, Delicious, Rome, and York Imperial as female parents, and Yellow Transparent,

Red Astrachan, Rome, Delicious, and York Imperial as male parents. These varieties were selected because it was felt that they represented fairly large differences in color, shape, size, acidity, and time of maturity. If the pollen of different apple varieties could influence the time of maturity, for example, the pollen of an early-ripening variety like Yellow Transparent might be expected to result in earlier ripening than where the pollen of York Imperial, a late maturing variety, was used. Under normal growing conditions the Yellow Transparent variety matures about 90 days before the York Imperial.

All blossoms were emasculated by removing the anthers from the filament with the aid of a medium-fine toothed comb. This method proved to be very satisfactory and caused no injury to the stigmas or to the calyx of the resulting fruit. Pollen of the five male parents was used in rotation on different spurs of the same branch. In other words pollen of one variety was used on the first spur, pollen of another variety on the second spur, etc., until the five pollens were used and then the process was repeated. Although this method required more time, still it was felt that this was the better method to use since the resulting fruit would be subjected to as near the same growing conditions as possible. Pollen was applied at the time of emasculation and the cluster was enclosed with a glassine bag.

With all the varieties used as females, some pollinations were made on trees with a heavy bloom and some on trees with a light bloom

TABLE I—RESULTS OF METAXENIA STUDIES WITH APPLES

Variety and Cross	Number of Apples	Number of Leaves per Apple[1]	Aver. Weight per Apple (Gms)	Aver. No. Seeds per Apple	*Height* Diam. Ratio
S. Rambo x Rome	11	limited[1]	138.0±4.4	3.63±.3	.74
S. Rambo x R. Astrachan	10	limited	129.6±4.6	3.10±.2	.77
S. Rambo x York Imperial	16	limited	125.6±3.2	3.25±.2	.77
S. Rambo x Y. Transparent	12	limited	121.0±3.8	2.83±.3	.76
S. Rambo x Delicious	14	limited	119.5±3.0	1.71±.2	.76
S. Rambo x R. Astrachan	14	abundant[1]	229.0±11.5	2.64±.2	.78
S. Rambo x Rome	16	abundant	215.6±11.5	2.93±.2	.76
S. Rambo x York Imperial	20	abundant	209.0±10.0	2.80±.2	.77
S. Rambo x Y. Transparent	9	abundant	206.1±14.0	3.10±.4	.77
S. Rambo x Delicious	12	abundant	205.0±11.1	2.66±.2	.75
Delicious x York Imperial	13	limited	188.0±2.8	7.69±.4	.89
Delicious x Y. Transparent	16	limited	174.6±4.4	6.68±.2	.89
Delicious x R. Astrachan	17	limited	171.1±4.9	6.52±.2	.89
Delicious x Rome	18	limited	164.2±5.2	6.88±.3	.88
Rome x Delicious	55	limited	114.2±1.4	7.43±.1	.79
Rome x Red Astrachan	52	limited	111.3±1.4	6.40±.2	.79
Rome x Y. Transparent	53	limited	110.5±1.4	6.56±.1	.79
Rome x York Imperial	51	limited	108.8±1.0	7.00±.2	.79
York Imperial x Rome	18	limited	132.7±3.0	7.61±.3	.81
York I. x R. Astrachan	8	limited	125.6±5.2	7.25±.3	.80
York I. x Delicious	30	limited	115.6±2.6	6.80±.2	.80
York I. x Y. Transparent	30	limited	113.5±1.4	5.66±.2	.79

[1]Limited = 14 to 20 leaves per apple.
Abundant = 100 or more leaves per apple.

in order that some of the fruits would be grown with a limited leaf area while some would be grown with abundant leaves. No set of fruit was secured, however, on the trees which blossomed lightly except in the case of Summer Rambo; therefore in all other varieties only fruit grown with a limited leaf area was available for these studies (Table I).

Results

At the time of harvest a numbered tag was tied to each fruit. The fruits were then examined by the authors, and several other persons, to see whether any of the characters of the pollen parents could be detected. At first the fruits were arranged in rows according to pollen parent. The persons examining the fruits were unable to determine which pollen parent had been used in the different rows of fruits. With later varieties, in addition to this method of examination, the individual fruits were examined one at a time by a number of persons. The correct determination of the pollen parent used varied from 16 to 23 per cent. Knowing that each fruit in the group had been pollinated by one of five pollens, one should have been able to have guessed correctly the pollen used in 20 per cent of the cases.

When the fruits were segregated into groups according to pollen parentage, no differences in the quality or quantity of color could be detected. Time of maturity, as indicated by ground color changes or ease of removal from the spur, was not influenced by the pollen parent. Thus it was clear that any possible effects of metaxenia, if they existed, could not be determined except through detailed measurements.

In addition to the general observations listed above measurements were made on the individual fruits including, weight of apple, diameter and height of apple, weight and number of seeds, and in some cases acidity and total sugar content. The height/diameter ratio was also determined (Table I).

The only characters which showed any appreciable variation when different pollens were used were weight of apple and number and weight of seed. Height and diameter and the height/diameter ratio were not affected; in other words the shape of the apple was not influenced by the pollen parent. Because of the high degree of correlation between number and weight of seed, only number of seed will be discussed.

Some of the larger differences in the average weight of apple between the different crosses are significant; as, for instance, the fruits resulting from the York Imperial by Rome crosses are significantly heavier than those from the York Imperial by Yellow Transparent crosses. As will be pointed out later, however, there were more seeds in the York Imperial by Rome crosses. More significance could be attached to these differences in weight if one particular pollen had always produced the heaviest fruit regardless of which variety was used as the female parent; and if at the same time another particular pollen had produced smaller fruit with all varieties. But this was not the case.

When the leaf area was limited, York Imperial and Summer Rambo fruits produced when Rome pollen was used were significantly heavier

than were fruits of these varieties produced when Delicious or Yellow Transparent pollen was used. With abundant leaf area Summer Rambo fruits produced by Rome pollen were also heavier than fruits produced by Delicious or Yellow Transparent pollen, though with these crosses the differences in weight were not significant. On the other hand Delicious fruits produced by Rome pollen were not as heavy as those fruits produced by Yellow Transparent pollen, but the difference in weight is not significant.

Although several investigators have studied the relationship existing between the weight of the apple and the number of seeds, their conclusions are not the same. Some investigators have found a positive correlation, some a negative correlation and some have found no correlation at all. All varieties used in this study showed a low correlation between weight of apple and number of seed. Using all the fruits produced on a given variety regardless of the pollen parent the coefficients of correlation were as follows: Summer Rambo (limited leaf area) +.19, Summer Rambo (abundant leaf area) –.28, Delicious +.37, Rome +.26, York Imperial +.23. The negative correlation noted with the Summer Rambo was caused by the presence of several large fruits which had developed without any seeds. When the fruits of the different female parents were grouped according to the pollen parent and the average weight of these groups compared with the average seed number of the same group, the coefficients of correlations were as follows, Summer Rambo (limited leaf area) $+.90 \pm .05$, Summer Rambo (abundant leaf area) $-.40 \pm .25$, Delicious $+.76 \pm .19$, Rome $+.44 \pm .27$, and York Imperial $+.87 \pm .08$. The negative correlation with Summer Rambo and the positive correlation with Rome are not significant, while the positive correlations with Summer Rambo, Delicious, and York Imperial are significant. In most instances the pollen parent which resulted in the greater number of seed also produced the greater weight of fruit, indicating that the larger fruits produced in most cases when Rome and Red Astrachan pollen was used may have been due to the greater number of seeds.

It might appear, as Nebel and Kertesz (23) have suggested, that by using as a pollenizer a variety which results in large fruit, such as Rome or Red Astrachan did in this study, larger fruits would be obtained commercially. In this study the York Imperial fruits produced by Rome pollen were larger than York Imperial fruits produced by Yellow Transparent pollen. However, if only Rome pollen had been used on an entire tree of York Imperial the resulting fruits probably would not have been any larger than if only Yellow Transparent pollen had been used, since the competing factor of seed number would have been removed and the size of fruits would have been determined to a large extent by the leaf area available per apple.

Acidity determinations were made on the juice of the Summer Rambo, Delicious, and Rome varieties. There was some variation but the pollen parent did not consistently influence the acid content of the fruit in any of these crosses. The total sugar content was determined for the York Imperial and Rome fruits. This material varied within narrow limits but was not influenced appreciably by the pollen parent.

Conclusion

Although the number of fruits available in each individual cross was rather limited in several cases, still the general agreement in the results obtained in the different crosses totaling 495 apples indicate that there was very little if any metaxenial effect of different pollens in this study. Similar studies will be conducted next year.

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Metaxenia in Dates

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EXPERIMENTS with dates, begun at the U. S. Experiment Date Garden, Indio, California, in 1925, have shown that pollen may affect not only the size, shape and color of the seed but also the size and time of ripening of the fruit itself. For this immediate influence of pollen on the somatic maternal tissue Swingle (8, 9) proposed the term "metaxenia" which has since been generally adopted as investigations in this field have been made with other crops in recent years.

Data from earlier experiments have already been recorded (1, 2, 3, 4, 5). The purpose of this paper is to summarize some of the later findings not previously published except for abbreviated references in reports of the work and its practical applications presented to the date growers (6, 7).

Because of its dioecious nature the date palm lends itself more readily to the investigation of metaxenia than many other crop plants. The character of its anemophilous floral structure also facilitates experimental pollinations. The inflorescence is a branched spadix with sessile flowers rather closely grouped along the distal portion of 25 to 100 or more spikes, 6 to 36 inches in length. A single very large inflorescence may carry up to 8000 or 10,000 flowers and more than 5000 dates have been counted on one extra large unthinned bunch. This makes it possible to get a large number of dates from a single pollination.

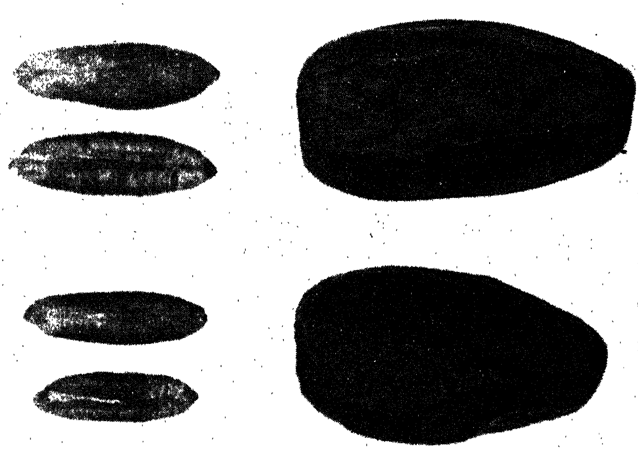

Fig. 1. Typical Deglet Noor fruit and seed produced by Mosque (larger) and Fard No. 4 (smaller) pollens on the same bunch. (Natural size.)

In experiments with wind-blown pollens care must be taken to prevent contamination or intermixture, but through a technic already described (2, 4, 5) different pollens have been tested satisfactorily

by applying several on a single inflorescence, each to a group of three or four spikes. Pollens from more than 200 different males have been tested in one or more such experiments in an effort to determine the maximum effects possible through metaxenia.

Results of Experiments

Two pollens, representing the upper and lower limits of effects produced by *Phoenix dactylifera* seedling males in the first year's experiments, were used in each test as standards of comparison. Of these two, Fard No. 4 pollen has consistently produced smaller fruit and seed ripening relatively early and Mosque, larger fruit and seed ripening relatively late. Pollens from no other seedling *P. dactylifera* males have gone significantly beyond their limits. A few other Fard seedling males have been tested that are comparable to Fard No. 4 and a number of males in commercial gardens have been found comparable to Mosque, but most of those tested have given results intermediate between the two.

The most convincing evidence of metaxenia is the data resulting from the application of the two standards, Mosque and Fard No. 4, and except as noted only these two are covered in this present summary. However, it should be stated that the object of these later pollinations was not primarily to prove whether metaxenia in dates exists, this having been accomplished by earlier data, but to explore the range of metaxenial effects by testing a large number of different pollens. All pollinations herein reported were on the Deglet Noor variety, although a lesser number of similar tests have been made on other varieties. In analyzing data from these experiments, all paired, the significance of differences has been determined according to "Student's Method" based on the ratio of the mean difference to the standard deviation. Table I is a summary of the differences produced by Mosque and Fard No. 4 pollens in 1930, 1932 and 1933, each experiment being on a single inflorescence. 1931 is not represented because in that year the Mosque male did not bloom until so late that it was necessary to substitute another somewhat comparable pollen in nearly all tests.

Due to the large number of pollens tested and the exploratory nature of the experiments no attempt was made to measure in days or weeks the actual difference in time of ripening of the fruit in all these experiments. As a matter of fact, though two or more observations on ripening were made in most of them, one observation at an optimum time, about the middle of the ripening period, would accomplish the objective of determining how the ripening produced by any particular pollen compared with Mosque and Fard No. 4. In each instance a count was made of the actual number of dates ripe, partly ripe, and immature and the results compared on the basis of percentage of the total for each classification. As ripening begins with a softening at the tip progressing toward the base of the date the distinctions between the three classes are readily made. As a single estimate of maturity, however, the ripe and partly ripe fruit have for convenience been grouped together. The observation showing the maximum difference in each experiment was logically taken for this summary because many

TABLE I—MEAN DIFFERENCES FROM POLLINATIONS WITH MOSQUE AND FARD NO. 4 POLLENS IN PAIRED EXPERIMENTS ON DEGLET NOOR DATES

Attributes Measured	Number of Experiments	Mean Difference	Standard Deviation
Season of 1930			
Number of dates ripe and partly ripe at one observation (per cent)	19	42.6±3.30	20.74±2.27
Length of dates (mm)	20	2.6±0.22	1.42±0.15
Breadth of dates (mm)	20	0.6±0.07	0.42±0.04
Length of seeds (mm)	20	3.0±0.15	0.95±0.10
Breadth of seeds (mm)	20	1.1±0.04	0.28±0.03
Weight flesh 10 dates (gms)	20	14.9±1.04	6.57±0.70
Weight 10 seeds (gms)	20	3.7±0.17	1.09±0.12
Season of 1932			
Number of dates ripe and partly ripe at one observation (per cent)	31	43.7±1.96	15.93±1.36
Length of dates (mm)	31	2.2±0.16	1.28±0.11
Breadth of dates (mm)	31	0.3±0.08	0.65±0.06
Length of seeds (mm)	31	3.0±0.13	1.05±0.09
Breadth of seeds (mm)	31	0.9±0.03	0.25±0.02
Weight flesh 10 dates (gms)	31	8.4±0.82	6.67±0.57
Weight 10 seeds (gms)	31	3.7±0.10	0.84±0.07
Season of 1933			
Number of dates ripe and partly ripe at one observation (per cent)	24	42.1±1.81	12.85±1.25
Length of dates (mm)	24	1.9±0.17	1.19±0.12
Breadth of dates (mm)	24	0.5±0.10	0.68±0.07
Length of seeds (mm)	24	2.3±0.13	0.91±0.09
Breadth of seeds (mm)	24	0.9±0.03	0.57±0.06
Weight flesh 10 dates (gms)	24	7.0±0.86	6.12±0.60
Weight 10 seeds (gms)	24	3.1±0.09	0.64±0.06

observations made either before any of the fruit from some pollinations had begun to ripen or after all of it had ripened were not representative. The magnitude of the mean maximum difference in percentage of fruit ripe and partly ripe at any one observation shows why it has never been necessary to resort to mathematical calculations to demonstrate the effect of pollen on time of ripening to those who have seen any of these experiments in the field during the ripening season.

Size data are based on the measurements of a random sample of 10 dates and seeds from each pollination, fruit to the nearest millimeter and seed to the nearest 0.1-millimeter. In some of the earlier experiments already reported (1) up to 100 dates and seeds per pollination were measured, but it was soon found that a smaller random sample was representative. The size data represent the average of means. For the weight data 10 dates were taken as a unit.

While the direct effect of pollen on the seed (xenia) is more pronounced than on the fruit (metaxenia), all the differences reported in Table I are significant, most of them highly significant. By weight the percentage increase of Mosque over Fard No. 4 ranged from 11.6 to 19.6 per cent for the entire date, 8.8 to 16.9 per cent for the flesh alone, and 46.3 to 52.9 per cent for the seed. These differences are for fresh weight. Data showing net increases of dry weight of flesh alone

have been reported for earlier experiments (1, 2). Eleven determinations in 1932 gave a mean difference per 100 dates of 79.1 ± 13.82 gms (standard deviation 64.81 ± 9.32), representing an increase for Mosque over Fard of 10.1 per cent.

Large Scale Demonstration and Application

In the practical application of metaxenia as regards increasing the size of fruit two factors must be considered. First, in commercial practice in the Southwest a date palm is never allowed to bear the maximum crop possible, and second, the thinning of bunches generally practiced also affects the size and time of ripening. These factors are now being investigated. They are mentioned here to guard against the deduction that because a certain increase in size of fruit has been consistently produced by pollen in experiments on single bunches, a corresponding increase in a total crop would be secured under commercial conditions. Although there is ample evidence that the size of the individual fruit and seed may be beneficially altered by the use of a different pollen in many instances, in field practice size is commonly controlled by bunch thinning. The total yield commercially desirable without sacrificing quality is determined by the size and vigor of the palm and it may usually be obtained with any good pollen.

Of more importance to the date grower is the possibility of being able to control to some extent the time of ripening and in date culture, more perhaps than in any other horticultural crop, metaxenia can be easily applied because artificial pollination is a commercial practice and there is obviously no more labor involved in the use of one pollen than another. The first experiments on a scale large enough to be regarded as a commercial demonstration were carried out in 1930. At the U. S. Experiment Date Garden five Deglet Noor palms in full bearing were pollinated entirely with Fard No. 4 pollen supplemented with some from another Fard seedling male known to produce the same effect on size and time of ripening. Five other comparable palms were pollinated entirely with Mosque pollen. The effects of pollen on the ripening of the fruit are shown in Fig. 2 plotted from weekly pickings throughout the season.

The difference in time of ripening at the U. S. Experiment Date Garden was about 15 days at the beginning of the season with a tendency to increase later on. Sixty-one per cent of the fruit from the Fard pollinations was picked in September and the harvest was practically over by November 1. On the other hand the Mosque pollinations ripened 33 per cent less of the crop in September and 17 per cent more after November 1.

Fig. 3 shows the results of a similar experiment at the Cook Date Gardens about 10 miles west of Indio. There only two Deglet Noor palms were used in each treatment and instead of Mosque pollen, Cook's No. 1, comparable in effect on time of ripening, was substituted. In this experiment the difference in time of ripening was greater than at the Indio station, being about 21 days at the beginning of the season and also showing an increase later. Twenty-two per cent more of the crop from the Fard pollinations ripened in September and only 9 per cent remained on November 1, whereas 55 per cent of the

crop from Cook's No. 1 was harvested after November 1 and over 12 per cent in December and January.

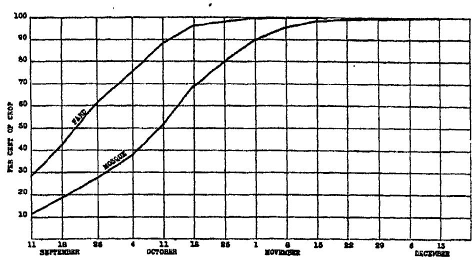

FIG. 2. Differences in time of ripening of Deglet Noor dates due to pollen. U. S. Experiment Date Garden. 1930.

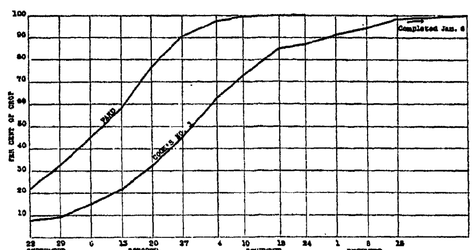

FIG. 3. Differences in time of ripening of Deglet Noor dates due to pollen. Cook's Date Garden. 1930.

While all the curves in Figs. 2 and 3 show a tendency for slower ripening near the completion of the harvest, it is apparent, as has been demonstrated by other tests, that differences in time of ripening due to pollen are less when the fruit ripens early and tend to increase when the season is late. Early in the fall when high temperatures usually prevail ripening proceeds very rapidly. Later in the season, when the weather is cooler, the fruit matures more slowly. Hence any difference in time of ripening due to pollen may cause the later ripening fruit to strike cooler weather which will further retard maturation. This fact has an important bearing on the commercial application of metaxenia in changing the time of ripening. As a consequence it is easier to accelerate the maturation of late-ripening fruit than to retard the maturation of early-ripening fruit.

In the vicinity of the Cook Gardens the ripening season is somewhat later than in most other date growing sections of Coachella Valley. One ranch in particular has had trouble with delayed ripening of the last 25 or 30 per cent of the date crop. Here experiments on two rows of 11 palms each, planned by the writer in 1931 and 1932, and carried out by H. R. Whittlesey, Manager of the Krutz Ranch, were very successful in the use of pollen to accelerate the ripening of this late-maturing fruit, as reported at the Tenth Annual Date Growers' Institute (10). In 1933 a pollination program based on these experiments was carried out for 17 acres of Deglet Noor dates with marked benefit. This is probably the first case on record of the commercial application of metaxenia to effect a change in the time of ripening of fruit.

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Further Observations on Frost Injury to Subtropical Fruit Plants

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IN December 1932, there occurred in the Sacramento Valley of northern California the most severe freeze on record. Its earliness, suddenness, severity, and duration all combined to cause the worst damage in the history of fruit-growing in that area. Injury occurred to a wide variety of subtropical fruit plants, which provided an unusual opportunity to study this phenomenon. Observations concerning the severity of the injury in relation to the temperatures which occurred have already been reported (1). It remains to summarize the kinds observed and the growth responses during the two seasons following the freeze.

KINDS OF INJURY-GROWTH RESPONSES

Several kinds of injury and growth responses were observed. Of the former a few were internal but most were external; of the latter at least one response was general even where no visible evidence of injury could be found. This was the development, usually in large numbers, of shoots on the lower part of the trunk, and was noted for the olive, fig, pomegranate and feijoa. The same response also occurred on injured trees of all kinds under observation, with the exception of the loquat, irrespective of location or severity of the injury.

Browning of the pith was observed in fruit-bearing twigs of both the Persian and native California walnuts, the sweet cherry, the pear, and in the fruit-spurs and buds of the almond. It has persisted for two seasons but the succeeding crops have been normal.

Injury to cambial tissues, but not involving death of the cambium, was observed both with and without evidence of bark injury. The first was noted in the walnut and olive, the second only in the fig. In the latter case no indication of injury was detected until the end of the growing season when a faint discoloration was observed in the cambial region. The limbs so affected either put out a few leaves, or none at all, but apparently made no growth. The next season they again failed to leaf out normally, though improvement was evident, and made little or no shoot growth. Examination at the end of the second growing season (1934) showed a pronounced discoloration in the xylem, outside of which there appeared to be but one growth ring. It would seem that there was little or no diameter growth the season following the freeze but a nearly normal growth the following season even though the leaf surface was much reduced. These limbs appear likely to make a complete recovery. This kind of injury occurrred only on the south and west sides of the trees.

Cambial injury was observed associated with two types of bark injury, killing and discoloration, both apparently extending in to the recent xylem. In the former, most in evidence on the walnut, new bark was regenerated rapidly, accompanied by the drying and splitting of the dead bark and the growth, through the cracks, of vigorous shoots. In the latter, also extensive on the olive, the discoloration disappeared rapidly. Injury of this type, though at higher tempera-

tures, was observed on young avocado trees following the freeze of January 1922, in southern California.

Marked discoloration of bark tissues, without evidence of cambial injury, occurred in the walnut, olive, carob and loquat. While most pronounced in the first two, recovery was so rapid that by the end of the following growing season the discoloration had either disappeared or was much less evident than in the last two, where it persisted well into the second growing season. As nearly as could be determined, whether by the growth of new bark tissue or the recovery of old, the discoloration disappeared simultaneously from both the outer and inner bark surfaces. This was most readily observed in the thick bark of the walnut. In the olive the restoration of the normal bark color was most rapid in trees and on parts where there remained a considerable number of uninjured leaves.

Injury involving the death of bark areas and the underlying cambium was particularly prevalent on the walnut and fig, and was also observed on the olive, pomegranate and feijoa. The growth responses noted were the usual healing-over from the live bark edges and the growth of shoots about the wounds. It was impossible to determine whether these developed from latent or adventitious buds.

The loquat excepted, bark injury of all types observed was confined mainly to the primary and secondary crotches and adjoining areas, to the trunks of young trees, and to points of previous injury such as pruning wounds and sunburn lesions. The latter are particularly prevalent on the south and west sides of fig trees and were the cause of much damage. On the walnut, under similar conditions, crotch injury was worse, and much more prevalent, in top-grafted trees than in nursery-grown trees. The bark injury observed on the loquat was confined to the trunk.

The killing of entire parts was general. Injury to the loquat was usually confined to the killing of the flower clusters and young fruits. Many individual limbs were killed in old fig trees, and some in olive trees. Such injury seemed to be confined to limbs lacking in vigor because of shading, or weakened from previous injury. Much damage resulted from the general killing back of the trees; this was characteristic for the evergreen sorts (guava, avocado, carob, citrus, prickly pear, olive, and feijoa), though it was also observed in some of the deciduous kinds (fig, walnut and pomegranate). The growth response which has occurred has been similar to that following pruning of like kind and severity. The more extensive the killing-back the more vigorous has been the growth response. The rapidity of recovery of moderately injured citrus and olive trees has been notable; some crop was produced the following season and nearly normal crops the season thereafter. The major difference in response was the subsequent dying-back, in cases of severe injury, of some of the new growth produced near the points of demarcation between living and dead tissues. This has been particularly marked in the tender evergreen sorts (citrus, avocado and carob).

The Major Kinds of Injury and Their Importance

Crotch injury to the walnut and severe killing-back of citrus, olive and fig trees were the major kinds of injury observed. While less

evident, in the former the seriousness of the injury is fully as great as in the latter because of the after-effects and the practical difficulties of rebuilding large walnut trees. Among the effects which have followed crotch injury have been the subsequent death of main limbs, serious crotch splitting and breakage, and infection with fungi which attack the heartwood. Some branches died the season following injury, others the next season, and still others seem not likely to recover. Breakage was especially prevalent the second season following the injury. In many cases the trees will have to be removed ultimately or rebuilt by budding or grafting a shoot from the crown. The killing back of bearing orange trees was severe and widespread and in many cases it will be advisable to replace the trees. The extent to which large citrus trees may be rebuilt is remarkable, however, though invasion with heart-rot fungi will ultimately cause many to decline. The successful rebuilding of severely injured olive and fig trees seems not to involve such difficult problems.

General Factors Affecting Recovery and Growth Responses

Aside from the degree of injury which occurred and the nature of the plant itself, the two general factors which seem to have most influenced recovery and growth responses have been the nutritional condition of the plant at the time of the freeze, and subsequent care. Plants lacking in vigor have responded slowly and much less satisfactorily, as have also those neglected since the freeze. This has been particularly evident with the citrus species and the olive.

Confirmation and Correction of Observations Previously Reported

The survey conducted during the present season (1934) has confirmed the observations previously reported concerning the degree and general nature of the injury which occurred at different temperatures, and evidences of differences in varietal resistance. The greater resistance of the two varieties of *Opuntia Ficus-indica* reported now appears to be due to the fact that they represent a different species, *Opuntia robusta.*

Further evidence has been observed of the relation between amount of crop and degree of injury in the olive. Much less injury occurred in comparable blocks of trees where the fruit had been thinned in late summer, approximately two-thirds of the crop having been removed. This, and other observations previously reported (1), are in agreement with the findings of Collison and Harlan (2).

Striking evidence of the effectiveness of orchard heating in reducing the degree of injury to citrus trees has been observed where the temperature in the orchard appears to have been only slightly affected by the heat released. The injury was much less and the recovery markedly better than in comparable areas not heated.

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Soil Variation and Its Relation to Winter Killing of Roots of Young Apple Trees

By L. P. Batjer, *Cornell University, Ithaca, N. Y.*

EXTENSIVE root killing of an irregular nature during the winter of 1933–34 in a large block of 3200, 4-year-old McIntosh, Delicious, and Cortland trees at Kinderhook, New York, suggested the possibility that soil variation was an important factor.

The Soil

The soil on which the orchard is located is correctly mapped (2) as Hoosic coarse sandy loam. It is a stream-laid terrace soil occurring in large areas, the topography of which is level to slightly undulating. The Hoosic soils are considered excellent for fruit, being very uniform and possessing an open porous structure with good to excessive drainage. The following is a description of a typical Hoosic profile. The surface 8-inch layer is a light brown, coarse, sandy loam, loose and friable. The 8 to 20-inch horizon is usually a yellowish brown, loose, coarse, sandy loam. Flakes of very small gravel, slate or shale are present which gives it a gritty feel. The upper part of the subsoil from 20 to 36 inches is a loamy coarse sand, of yellowish brown to light grayish brown color. It is loose and incoherent. Below 36 inches it consists of alternating layers of dark, grayish brown, coarse sand and very small gravel.

Numerous borings to a depth of 4 feet, taken at regular intervals over the site in question showed scarcely any variation in color, texture and depth of the various horizons.

Treatment of Soil Before and After Setting of Trees

For two seasons prior to setting the trees the entire field was planted to corn which received a side dressing of sodium nitrate. The stalks were turned under in the fall. In the spring of 1930, 2400 trees were planted on the south portion of the field and corn was again planted on the entire area. Ammonium sulphate was applied at the rate of 125 pounds per acre. The corn was disked and plowed under in a green condition. In 1931, the remaining portion of the field including 800 trees was planted. Sweet clover was sown in the spring with a 25 pound per acre application of sodium nitrate. The following year (1932) ammonium sulphate was applied at the rate of 35 pounds per acre. The sweet clover made a good growth. In 1933, ammonium sulphate was applied at the rate of 1½ pounds per tree. The volunteer sweet clover was disked under in May and clean cultivation was practiced in June and July. The field was again disked in November rendering the soil bare during the severe winter which followed. In the spring of 1934 each tree received 2 pounds of sodium nitrate.

Effect of Severe Winter (1933–1934)

At Albany, the nearest Weather Bureau Station, the rainfall for November and December, 1933, was 4.4 inches, a deficit of over an

inch for this period. The minimum temperature recorded for December was –21 degrees F, January –6 degrees F, and February –20 degrees F. Rather extensive root killing resulted with all varieties. A survey of the injury in June showed 38 per cent of the trees dead and 15 per cent definitely injured. A greater per cent of killing occurred on the east end of the planting (which was probably more windswept) but it was more or less spotted over the entire area. A single row of 59 trees (row No. 9) in the middle of the planting presented a marked contrast with the rest of the orchard in that it did not contain a single dead tree. This row happened to be located on what had been an old fence row for years prior to the planting of the orchard. Fig. 1 shows a typical cross section of the east end, where killing was the most severe, as it appeared in June, 1934. This shows clearly the striking difference that existed between row No. 9 and an adjoining

FIG. 1. A typical view of the east portion of the orchard as it appeared in June, 1934.
The rows of trees at the left, (row 9) is uninjured; The row at the right shows both living and dead trees which is characteristic of the rest of the orchard. Trunk circumference measurements showed no difference in size between normal and dead trees.

row. Root injury is commonly associated with dry soil of light texture. Emerson (1) and others have reported a relationship between the moisture content and root killing in a light sandy soil.

It seemed conceivable that differences in moisture holding capacity whether produced by variations in organic or mineral materials might have been responsible for the differences in injury encountered in this orchard. Accordingly, 42 live trees were selected in a typical section of the orchard, each tree being paired with the nearest dead tree (never more than two rows distant) of comparable variety. A composite surface soil sample was then taken from around each of the 84 trees and brought to the laboratory for analysis.

Results of Soil Analysis

Per cent loss on ignition was used as an indirect measure of organic matter. The errors involved in using this method to measure organic matter are fully realized. It would seem, however, that it could be used to advantage since the soil was free from calcium carbonate and due to its extreme light texture possessed a relatively low amount of combined water.

The values for per cent loss on ignition are shown in Table I. The data were divided into two groups. In column 1, 24 uninjured trees in row 9 are each paired with the nearest dead tree (column 2). Column 3 shows values for 18 uninjured trees not located in row 9, and column 4 to the nearest dead tree to each living tree listed in column 3. These data were analyzed statistically according to students' "Z" method. In group 1 the mean difference in favor of the living trees is .74 per cent, while in group 2 it is .37 per cent. These differences support significant odds of 999: 1 and 82: 1, respectively.

TABLE I—Relationship of Per cent Loss on Ignition in the Hoosic Soil to Root Injury of Young Apple Trees During the Winter of 1933–34

Group 1			Group 2		
Pair No.	Uninjured Trees in Row 9 (Former Fence Row) 1	Nearest Dead Tree 2	Pair No.	Uninjured Trees Other than Row 9 3	Nearest Dead Tree 4
1	5.53	5.00	1	5.24	4.15
2	5.87	5.25	2	5.31	5.01
3	5.41	4.10	3	6.10	5.39
4	6.13	5.39	4	3.58	4.64
5	5.79	5.44	5	4.28	4.07
6	5.62	5.92	6	5.08	4.43
7	5.86	4.80	7	3.73	4.64
8	5.38	4.06	8	5.65	4.90
9	5.58	4.63	9	3.84	3.20
10	5.45	4.55	10	3.56	2.86
11	5.37	3.79	11	3.74	3.59
12	5.75	4.08	12	5.13	4.30
13	5.12	3.92	13	5.23	5.24
14	5.32	4.03	14	5.17	4.95
15	4.69	3.82	15	5.45	3.94
16	4.80	4.16	16	3.72	3.44
17	4.06	4.08	17	5.23	4.64
18	4.35	4.21	18	4.92	4.94
19	4.60	3.69			
20	4.38	3.91			
21	4.10	3.14			
22	4.04	3.98			
23	4.65	4.18			
24	5.50	4.53			

It will be observed from the data in Table I that a large number of dead trees have a higher value for organic matter than uninjured trees occurring in a different pair. This may be due to an unequal snow cover in different parts of the orchard. Hence the pairing as

shown in Table I was done in order to reduce this chance of error to a minimum.

In general a relatively low per cent loss on ignition is associated with injury. It may be argued that the difference in ignition loss on these soils is not due to variation in organic matter but due to differences in mineral content. In order to check on this point, 14 soils were selected for N determination (Kjeldahl method not to include nitrates) which varied from 3.12 to 6.33 in per cent loss on ignition. This data is presented in Table II along with moisture equivalent values (3) for the same soils. The soils show approximately the same rank in organic matter if this value is based on the nitrogen content or loss on ignition. There are, of course, some exceptions. Whether the differences in these soils is organic or mineral is therefore a matter for speculation. The significant point, however, is that such wide variations (in both N and loss on ignition) occur on one of the most uniform fruit soils in New York State.

TABLE II—DIFFERENCES IN SOIL PROPERTIES IN VARIOUS PARTS OF THE JUDSON ORCHARD, KINDERHOOK, NEW YORK

Location by Tree No.	Per cent Loss on Ignition	Moisture Equivalent	Per cent Nitrogen
11–50	6.33	19.08	.166
11–51	5.90	17.72	.130
9–8	5.87	14.78	.092
9–28	5.62	15.55	.113
7–3	5.46	15.08	.076
13–7	5.04	14.33	.076
8–53	4.53	14.15	.086
12–44	4.48	14.15	.098
9–40	4.42	13.79	.084
9–37	4.06	13.50	.079
10–56	4.02	12.46	.052
11–31	3.74	11.90	.070
13–21	3.53	11.70	.070
0–41	3.12	11.11	.057

It is interesting to note how closely the moisture equivalent checks with the loss on ignition values (Table II). If we accept moisture equivalent as a measure of the field capacity of the soil (4) then the data in Table II show that these soils vary from 11 to 19 per cent in their absorptive capcity. Such a marked difference as this in light textured soils of the Hoosic type would certainly be reflected in plant response. A calculation shows that the soil with a 19 per cent field capacity (if saturated by rain and allowed to drain) would be able to supply a mature apple tree with approximately 700 gallons more water in the surface foot of soil than the soil with an 11 per cent field capacity. This amount of water is equivalent to an inch of rainfall.

Effect of Crop and Treatment on Winter Injury to Baldwins[1]

By MARY A. TINGLEY, and G. F. POTTER, *University of New Hampshire, Durham, N. H.*

THE low temperatures of the winter of 1933–34 have caused considerable injury to fruit trees in New Hampshire. Conditions seem to have been especially critical for trees of the Baldwin variety, such that the difference in susceptibility due to fruit bearing in many instances was the determining factor in survival.

At the Experiment Station in Durham a frost in the spring of 1932 killed all Baldwin blossoms. Therefore in 1933 all trees of this variety were in bearing. The minimum temperature for the winter, –31 degrees F, was reached on December 29. With few exceptions all Baldwin trees of bearing age were severely injured or killed. Some striking variations in severity of injury occurred in the so-called Renovated Orchard at the Horticultural Farm, a block of Baldwins about 50 years old.

While the number of trees involved was too small to permit of statistical study, it seemed worthwhile to make estimates of the injury and to present these and some photographs herewith.

The orchard comprises 10 rows, originally of seven trees each. Since 1918, six of these have been under different cultural conditions, the other four being used as division rows. The treatments per tree for the six rows were as follows:

1. Cultivation and cover crop, 400 pounds barnyard manure.
2. Cultivation and cover crop, 5 pounds sodium nitrate.
3. Cultivation and cover crop, complete fertilizer containing 5 pounds of sodium nitrate.
4. Sod mulch, 400 pounds barnyard manure.
5. Sod mulch, 10 pounds sodium nitrate.
6. Sod mulch, complete fertilizer containing 10 pounds sodium nitrate.

All fertilizer applications were made annually in early spring.

On account of lead residue agitation various substitutes for the standard lime-sulfur-lead-arsenate spray mixture were under test at this station in 1933. Three mixtures in which calcium arsenate was used in place of lead arsenate in the late cover sprays were applied in the Renovated Orchard to rows running crosswise of the fertilizer treatments. Early in the spring a striking difference in degree of winter injury was noticed between two of the rows sprayed with mild sulfurs and the rest of the orchard. This difference became more pronounced as the growing season advanced. The outside row on the northeast side of the orchard, which had been sprayed with flotation sulfur plus calcium arsenate, was injured very little, and the adjacent row, which had received a mixture of flotation sulfur and dilute lime-sulfur plus calcium arsenate, only slightly more. The third test row was sprayed with Kolofog plus calcium arsenate. Customarily extra lime is added to all mixtures containing calcium arsenate, but by

[1]New Hampshire Contribution No. 47.

FIG. 1. Left, row sprayed with flotation sulfur plus calcium arsenate; right, with a mixture of flotation sulfur and dilute lime-sulfur plus calcium arsenate.

FIG. 2. Trees which in July cover sprays received some standard lime-sulfur plus lead arsenate or calcium arsenate.

error it was omitted from the last application in these three rows. No bad effects from those mixtures containing flotation sulfur were noted, but in combination with Kolofog serious spray burn and defoliation resulted. Winter injury to this row was strikingly increased.

The trees in the remainder of the orchard were sprayed indiscriminately with materials left over from adjoining spray test plots. These consisted of lime-sulfur plus lead arsenate, lime-sulfur plus calcium arsenate plus lime, and flotation sulfur plus calcium arsenate plus lime. No visible spray injury occurred in this part of the orchard, but winter injury was severe. This was true also of vigorous 18-year-old Baldwins in the adjoining spray plots to which the standard lime-sulfur-lead-arsenate mixture had been applied throughout the season. (Figs. 1 and 2.)

In October the trees were classified on the basis of the extent and vigor of the leaf area into eleven groups ranging from no injury (0 per cent) to completely killed (100 per cent), with nine intermediate classes at 10 per cent intervals. The estimates were made independently by two persons. After comparison the few cases of slight disagreement were reconciled. Only two trees were considered to be normal and these, no doubt, would show injury in the wood.

The yield for 1933 was calculated in pounds of fruit per square decimeter of cross-sectional area of the trunk. These data together with the estimates of injury are shown in Table I. The figures in the second column show the average injury in the six experimental rows, while those in the last column include the division rows, for which there are no yield records.

TABLE I—The Average Yield per Square Decimeter of Cross-sectional Area of the Tree Trunks and the Average Per cent of Winter Injury in the Spray Test Rows

Row	Yield (Pounds)	Injury (Per cent)		
		Experimental Rows	Division Rows	Entire Row
Mild (flotation) sulfur with calcium arsenate	76	33	5	22
Mild sulfur and lime-sulfur	54	33	25	30
Mild sulfur (Kolofog) with calcium arsenate	47	60	63	61
Remainder of orchard	67	62	57	60

The difference in injury cannot be explained on the basis of yield. It would seem that the different spray treatments may have been factors in determining the amounts of injury. It is known that decreased leaf area due to defoliation, severe pruning, or other similar causes, has often been a contributing factor in susceptibility to winter injury. Presumably some product of photosynthesis is involved. Hoffman (1, 2) has presented evidence to show that applications of lime-sulfur solution materially reduce photosynthesis. It seems likely, therefore, that the survival of the two rows sprayed with mild sulfur is related to a greater efficiency of the foliage on these trees.

FIG. 3. Row fertilized with 10 pounds of sodium nitrate per tree annually.

FIG. 4. Left, each tree received 400 pounds of manure each year.

The greatest injury occurred in the manure rows. In the sod row every tree was dead except the two sprayed with mild sulfur, and even those displayed only about 20 per cent of normal foliage. (Figs. 3 and 4.)

Table II shows the yield and estimated injury in the fertilizer test rows. Here yield may have had some influence, but the difference in injury between the manure and the nitrate rows seems greater than can be explained by differences in yield alone. Possibly the manure delayed maturity.

TABLE II—THE AVERAGE YIELD PER SQUARE DECIMETER OF CROSS-SECTIONAL AREA OF THE TREE TRUNKS AND THE AVERAGE ESTIMATED PER CENT OF WINTER INJURY IN THE FERTILIZER TEST ROWS

Row	Yield (Pounds)	Injury (Per cent)
Sod nitrate	56	33
Sod manure	67	93
Cultivated nitrate	56	37
Cultivated manure	77	56

The cultivated manure row is on the southeast edge of the orchard and therefore would seem to be in a more favorable position for photosynthesis. This location may explain its greater resistance over that of the sod row.

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Seven Years' Results of the Hardiness of Elberta Fruit Buds in a Fertilizer Experiment

By R. L. McMunn, and M. J. Dorsey, *University of Illinois, Urbana, Ill.*

IN a climate so variable during the winter months as that of the peach district of southern Illinois, the question is often raised by growers as to the effect of the usual fertilizer applications upon the winter hardiness of the fruit buds. Since rather pronounced growth differences were induced by the fertilizer applications used in the L. S. Foote orchard, Johnson County, it seemed advisable to determine the amount of bud injury for a number of seasons in order to learn something of the possible hazards or benefits over a period of years which may be incurred from such treatments. The results of these studies cover a period of seven winters.

Plan of the Experiment

The soil type:—The soil type in the orchard has been classified in the Illinois Soil Survey system as a yellow silt loam, No. 135. This soil type is but 2 to 3 inches deep, brownish-yellow in color, friable, invariably acid, and very low in nitrogen and organic matter. A true surface soil is seldom found, however, because of the erosion which has taken place. The subsurface is about 18 inches deep, "and consists of a light grayish yellow, friable, silt loam" (1). In the orchard where the plots were located, the surface soil had been washed away, leaving a subsurface soil 6 to 16 inches in depth. This soil type, however, was very uniform in the different plots. Due to the low nitrogen content, the peaches showed a marked response to nitrogenous fertilizers in shoot growth, leaf size, leaf color and yield. Although the soil is invariably acid, 1 ton of limestone per acre generally corrects the acidity, so that a good crop of legume cover crops can be grown in the orchards.

The experimental plots:—In 1925 in an orchard planted 25 x 25, 14 plots of 42 trees (6 x 7) each were laid out in a fertilizer experiment. The plots were located on some of the highest ground in the vicinity, and were placed so that no appreciable amount of surface water passed from one plot to another during heavy rains. A wide deep valley close by offered excellent air drainage. At the start of the experiment, the trees were 3 years old and quite uniform in size. During the summer of 1925 the effect of withholding nitrogen was very noticeable on the check plot, No. 4, so, in the spring of 1926 a part of it was fertilized. This addition to the series is shown as Plot 20 in Fig. 1. By 1928 the trees in the check plot were so reduced in vigor that they were making but an inch or so of terminal growth per year. Consequently, starting in 1928, these trees were given 8 pounds of nitrate of soda each on July 10, and each succeeding year thereafter in order to study the rapidity of recovery and the time of maturity in the fall. All plots except the check, No. 4, were divided the long way, making 21 trees in each side; to one half nitrate of soda was applied, to the other half ammonium sulfate. The data were taken on the

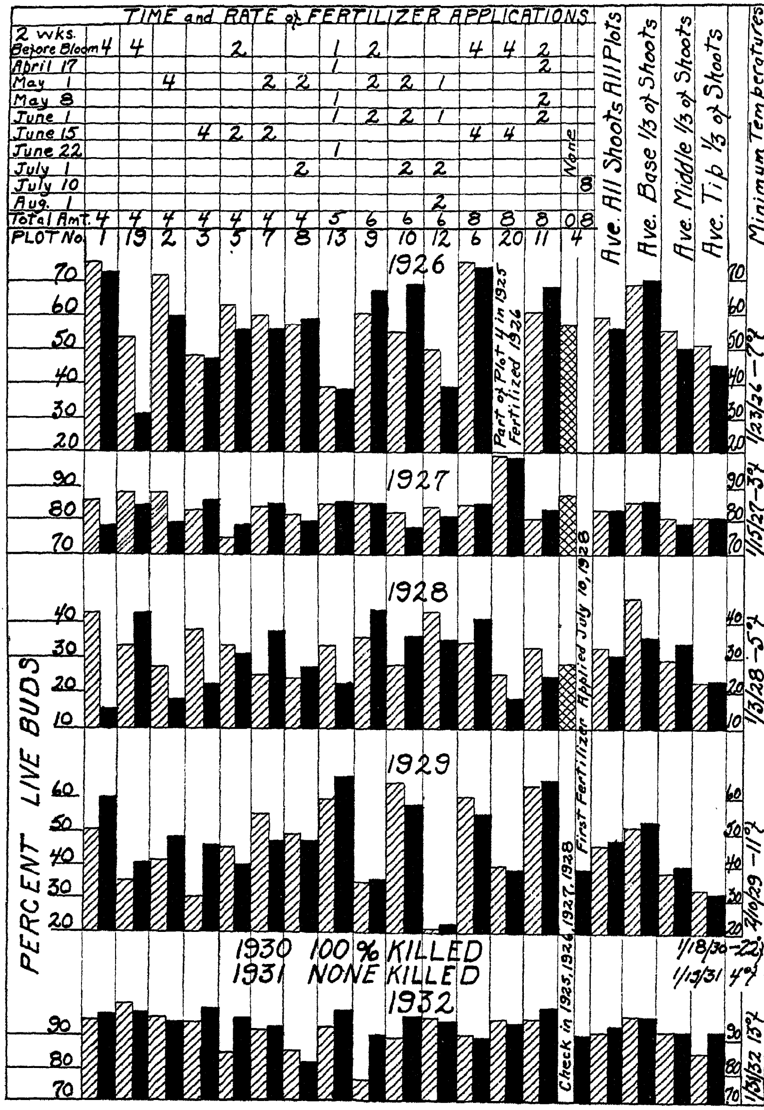

Fig. 1. Showing the time and rate of fertilizer applications, the minimum temperatures, and the percentage of bud survival. The solid bars are for the half of the plot receiving nitrate of soda, the hatched bars for the half receiving ammonium sulfate.

interior five trees of the plots thus divided. Nitrate of soda and ammonium sulfate were applied on the nitrogen basis, i.e., 4 pounds of nitrate of soda were considered equal to 3 pounds of ammonium sulfate. In Fig. 1 the rate of application is entered for ammonium sulfate only; the pounds of nitrate of soda applied on the nitrate side of the plots can be determined by multiplying by the factor 1.33. The time and rate of application are shown at the top of Fig. 1. The applications to be applied 2 weeks before bloom were not always timed accurately; consequently the seasonal factor entered a variable of from one to three weeks before bloom. Plots 11 and 13 were fertilized at 3-week intervals after full bloom. These applications are placed at April 17, May 8, June 1, and June 22, this being the average date of applications. The cultural treatment, spraying, pruning and thinning were alike for all plots.

Ten typical outside terminal shoots located from 5 to 8 feet from the ground were collected while the fruit buds were in the "pink" from each of the inside trees in the nitrate and ammonium side of the plots. Each shoot was divided into three equal parts and the fruit buds on each section were examined macroscopically for bud killing. The shoots used in this study were also used in checking on the bud level (2). The total number of buds examined and counted each year ranged from 8,641 in 1928, a year of low bud level, to 20,882 in 1929, when the bud level was high—a range of about 600 to 1,400 buds per plot. The data on the percentages of live buds are shown as bar graphs in Fig. 1; the solid bars representing the bud survival for the trees receiving nitrate of soda and the hatched bars the trees receiving ammonium sulfate. The "average all shoots all plots" shown in Fig. 1 does not include Plot 4; neither does the data on the base, middle, and terminal thirds include Plot 4. In the previous report (2) there is recorded no crop for 1932, while in this paper the bud survival is shown to be around 90 per cent. This difference is due to a late freeze March 5–11, 3 days after the bud counts were made, which killed all of the flowers.

Results

Bud survival:—Referring to Fig. 1 it will be seen that the average bud survival of all the fertilized plots varied from 100 per cent kill in 1930 to no injury in 1931. It will be seen from the graphs that the fruit buds were as hardy in Plot 4 during the 3 years it was carried as a check plot as the average of all the fertilized plots.

Of interest also is the number of buds that survived when subjected to different degrees of cold. Thus, in 1929 the average for all the trees given sulfate of ammonia was 47 per cent survival as compared with 48 per cent for those given nitrate of soda. The fruit buds of 1929 were subjected to a temperature of –11 degrees F on February 10; previous to this, the minimum temperatures had been near the freezing point with the daily maximum above freezing. The day before, February 9, the maximum temperature was 30 degrees and the minimum 11 degrees. On the 10th the maximum temperature was 26 degrees, which, with a minimum of –11 degrees, represents a drop of 37 degrees in 24 hours. Following the level reached on February 10,

the temperature rose again to above freezing. The bud survival in 1929, however, was higher than in 1928, even though the buds of 1928 were exposed to temperature of only –5 degrees F. This difference is interesting in view of the fact that the low temperature of January 3, 1928, was preceded by temperatures in December, which reached a maximum of 60 degrees on the 29th, 57 degrees on the 30th, and 41 degrees F on the 31st. A sudden drop to a minimum of –4 degrees on January 1 and 2, and of –5 degrees on the 3rd, followed by minimums above 32 degrees subjected the buds to as great a change as that which occurred in 1929.

The sudden changes in temperature do not appear, however, to be the explanation for the greater bud killing in 1928. If such were the case, a far greater bud kill should have occurred in 1926, when a minimum level of –7 degrees F on January 23 was preceded by 3 weeks of weather when the maximum temperatures were well above freezing, several days even being above 50 degrees F. It would seem, upon analysis, that certain features of the growing season of 1927 might have a bearing upon the bud killing on January 3, 1928.

In the spring and early summer of 1927 an excess of rainfall fell in March, April, May, June, and July. This prolonged wet period thoroughly saturated the soil during the early part of the season. An examination of the root systems of peach trees in the Foote orchard as late as June 27 revealed that no new roots had as yet been formed. That growth conditions were unfavorable was shown in part by a heavy drop of fruit after the normal June drop, which at the time was attributed to the very wet soil.

A heavy crop should, likewise, lower the hardiness of the fruit buds. Comparing the average killing in 1931 and 1932, it will be seen that there was no killing in 1931 with a temperature of 4 degrees F, while in 1932 from 3 to 25 per cent (average 7.5 per cent) of the buds were killed, even though the temperature reached a minimum of but 13 degrees F. The buds formed for the 1931 crop were subjected to temperatures below 20 degrees on but 17 days during the winter, and those for the 1932 crop to but 3 days below 20 degrees. The buds of 1931 were formed in 1930 when the trees were carrying no fruit; those of 1932 were formed when the heavy crop of 1931 was being produced. Also, the bud crop of 1926 was formed while no crop was being produced.

Knowlton and Dorsey (3) and Crane (4) and others have pointed out the greater hardiness of the basal buds. The data reported here is in line with their findings since the fertilizer applications did not induce greater hardiness in the terminal buds as compared with the basal buds. It will be noted, however, that there is little difference in hardiness between the fruit buds borne on the middle and terminal parts of the shoots when the killing is light, as in 1927 and 1932.

Chandler (5) found a greater per cent of the buds surviving on trees that were induced into a late growth either by pruning, late fertilizer applications, or cultivation, than on trees not producing a late growth. Crane (4), however, found late applications to increase the percentage of bud killing. If late applications of fertilizer produced hardier buds than early applications, or vice versa, it would be ex-

pected that the buds from plots 8, 10, and 12 (and 4 after 1928), all of which had late applications, should have hardier buds than the plots receiving earlier applications. Comparing the killing of these plots with the other experimental plots, it will be seen that late applications did not induce greater fruit bud hardiness nor cause them consistently to be more tender than on trees receiving earlier applications. Evidently in this series of plots some factor or factors other than the time or the amount of fertilizer applied determined to a large extent the hardiness of the fruit buds. From these data it can be seen that conflicting results could easily be secured in experiments which were carried on for only a year or two.

In this orchard very marked responses in shoot growth, leaf size and color were induced by the fertilizer applications. This was especially true during the first 4 years of the experiment while the trees were young. It is during the first part of the tests, on account of the greater growth stimulus at that time from the fertilizer applications that one might expect influences upon fruit bud hardiness to be the most pronounced. Even the higher applications of nitrate of soda or ammonium sulfate, however, did not increase, or decrease, the hardiness of the buds as compared to plots receiving lesser amounts or the check plot. Neither did "splitting" the applications seem to have any influence in producing hardier fruit buds.

The results of this phase of the Illinois peach studies seem of significance from the following angles: (1) Within the range of vigor induced by the different fertilizer treatments—1 inch to 2 feet as measured by terminal shoots—the hardiness of the fruit buds were not significantly affected one way or the other in the 7-year period; (2) the individual plot variations indicate something of the desirability of extending studies of this nature over a series of years before drawing conclusions; (3) there is some indication that heavy crops and an unfavorable growing season characterized by excessive rainfall and a saturated soil up to July in this instance, tended to lower the hardiness of the fruit buds formed under such conditions. These points seem to be independent of the greater quantity of fruit buds borne on the longer shoots induced by the fertilizer treatments.

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Studies on the Resistance of Peach Buds to Injury at Low Temperatures

By F. P. CULLINAN and J. H. WEINBERGER, *U. S. Department of Agriculture, Washington, D. C.*

THE destruction of blossom buds of the peach by low temperatures during the dormant season is known to vary with varieties and stage of development of the buds. Temperatures which result in total destruction of all flower buds of a known variety will vary with the time of season when these temperatures occur in any given latitude and with the seasonal temperatures which have preceded the period of injury. Observations made over a period of years, however, have suggested that not only do varieties vary in their resistance to injury at low temperatures, but that there is a wide difference in the survival of buds on trees of the same variety in a given locality. Work previously reported by the senior author (3) has shown differences in the amount of blossom injury on trees growing under cultural conditions which produced shoot growths differing widely in vigor. In order to study further any relationships between vigor and hardiness, as well as to determine varietal differences, studies were made during the winters of 1932, 1933, and the fall of 1934, on the survival of blossom buds when subjected to low temperatures under controlled conditions.

Buds were exposed in a freezing chamber in which the temperature could be kept constant at any minimum desired by thermostatic control. Temperatures within the chamber were recorded on a thermograph placed adjacent to the sample. The samples to be frozen were always put in the chamber in the same location with reference to the thermograph and thermometers, and at the same distance from the freezing unit and sides of the chamber. Ample room for air circulation was provided around the samples.

Samples of twigs containing about 200 buds for each variety were taken in the orchard, labeled, taken immediately to the laboratory, and placed in the refrigerator. Where long shoots were used, they were cut into sections and bud behavior on different portions of the shoots determined. After a number of preliminary trials on time of exposure and rate of temperature fall within the chamber, it was found most convenient to expose the samples for a period of 18–20 hours to the degree of cold required to kill about 50 per cent of the buds; after which they were allowed to stand for a similar period, usually 24 hours, in a room of moderate temperature (50–60 degrees F) under conditions where excessive desiccation would not occur. Following this after-freezing period the amount of injury and death of the tissues could be detected easily by sectioning the bud through the floral axis and noting the browning of the injured parts. Microscopic examinations were frequently used to determine the degree of injury.

During the winter of 1932–33 many preliminary tests were made to determine the effect of rate of temperature fall on the degree of injury. As shown by Chandler (1) the rate of temperature fall is important in determining the amount of injury at a given temperature.

It was found difficult to lower the temperature at the same rate for samples tested on different days; consequently, the buds were placed in the freezing chamber and the temperature was allowed to fall to the minimum for which the thermostat was adjusted. The temperature at which injury occurred in the freezing chamber was used as a measure of the relative hardiness of the buds at that particular time. The data are therefore to be regarded as a measure of relative hardiness, and not as the absolute minimum temperatures which these buds would undergo without injury in the field.

Results

Results in 1932–33:—Observations were started on November 8, 1932, and continued until March 28, 1933, when the buds were showing pink. Many varieties were examined during the period, but data for Elberta and Greensboro presented graphically in Fig. 1 for the early part of this period, with the inclusion of Carman and Hiley later in the season, will show the trend of resistance to cold injury. In the graphs the percentage of injury occurring to Elberta at any particular period is used as the base, and the percentage of injury of other varieties is shown in relation to Elberta for the particular sampling dates and for the temperatures maintained in the chamber on those dates.

During November the temperature range, resulting in the death of a large proportion of flower buds of Elberta, was from 20 degrees F on November 8, to 14 degrees on November 26, or a drop of 6 degrees. The average minimum air temperature for the month was 35.9 degrees, with the lowest minimum of 18 degrees reached on November 26.

During December there was little change in hardiness in the buds. The mean minimum temperature for the month was 30.9 degrees F, with the low of 14 degrees reached on December 16. By early January, freezing tests showed the buds to be more resistant to cold injury than during the previous month. The maximum cold resistance was reached in the samples taken on January 21. Shortly after this date and late in January the buds became markedly less resistant. In the 14-day period from January 15 to 29, the minimum temperatures were above 32 degrees, and the average mean for the month was 9.2 degrees above normal. The rest period was ended and the blossom buds were swelling. During the early winter period Greensboro was distinctly more hardy than Elberta. Two other varieties tested, Carman and Hiley, also showed marked difference in hardiness. With the development of the buds during February and March, Hiley became increasingly tender. The order of hardiness during late winter, as shown in Fig. 1, was Greensboro, Carman, Elberta and Hiley.

Results in 1933–34:—Observations were started on November 9, 1933, and were terminated when the severe cold on February 9 killed practically all of the flower buds except on a few hardy varieties. On the initial date, buds withstood a temperature of 12 degrees F in the refrigerator without serious injury (Fig. 2). The temperatures were lowered steadily during this month. A total drop of 12 degrees in as many days to 0 degrees resulted in the death of all Elberta buds at the latter temperature by November 22. Buds showed greater hardi-

ness during November and December in comparison with the same months in the previous season. The average minimum air temperature for November was 37 degrees; December, 30.3 degrees; and January, 31.5 degrees; in 1933–34, as against 35.9, 30.9, and 34.5 degrees, respectively, for 1932–33. In contrast to the previous season, the low temperatures in January were less favorable to bud development, and buds exposed to low temperatures during January and early February were quite resistant.

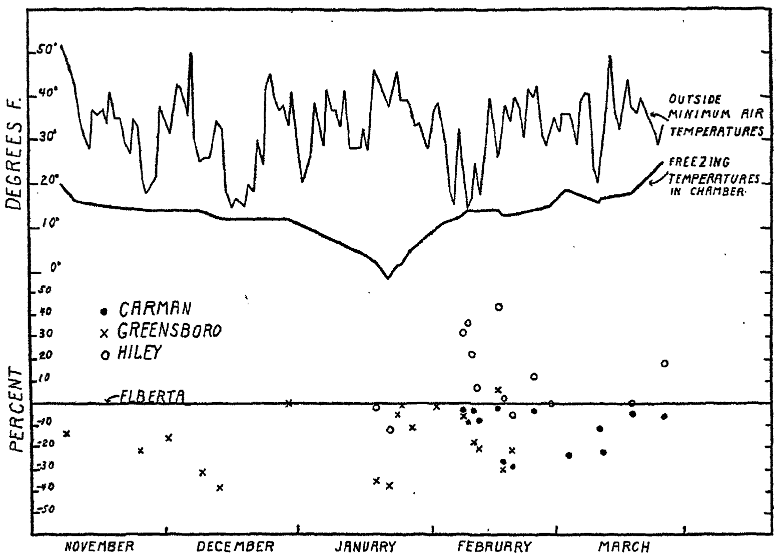

FIG. 1. Percentage of blossom buds of varieties of peach injured at temperatures maintained in freezing chamber during 1932–33 relative to the per cent of injury to Elberta as a base, and with out-door minimum temperatures occurring during period of tests.

It was noted in the season's studies that in late fall and early winter, Elberta samples showed no more injury to test temperatures than Belle or Carman. However, in late winter the order was reversed. Thus, as in 1932–33, the order of greatest hardiness in late winter was Greensboro, Carman, Belle, Elberta, and Hiley.

Results in 1934:—In the fall of 1934, freezing of buds was begun October 1, just prior to full leaf fall, and a month earlier than in the two previous seasons. On this date there was no injury to blossom buds at a temperature of 24 degrees F. By October 5, a temperature of 14 degrees F killed 70 per cent of the buds on Elberta and caused severe injury to the twigs. Not until October 25 could the temperature of the freezing chamber be dropped much below 17 degrees without some injury to the twigs. Frequently the blossoms were not injured at temperatures which caused severe injury to bud scales and to the cambium and outer xylem of the shoot. Since the observations

for 1934–35 are not completed, a summary only of the data for the early season are presented here.

During the month of November the buds of all varieties hardened off rapidly. Between November 1 and 19 the temperature in the freezing chamber was dropped a total of 10 degrees in keeping pace with the developing hardiness of the buds to injury. Two points were of interest in the observations made during this period. First, varieties collected from three different orchards varied considerably in

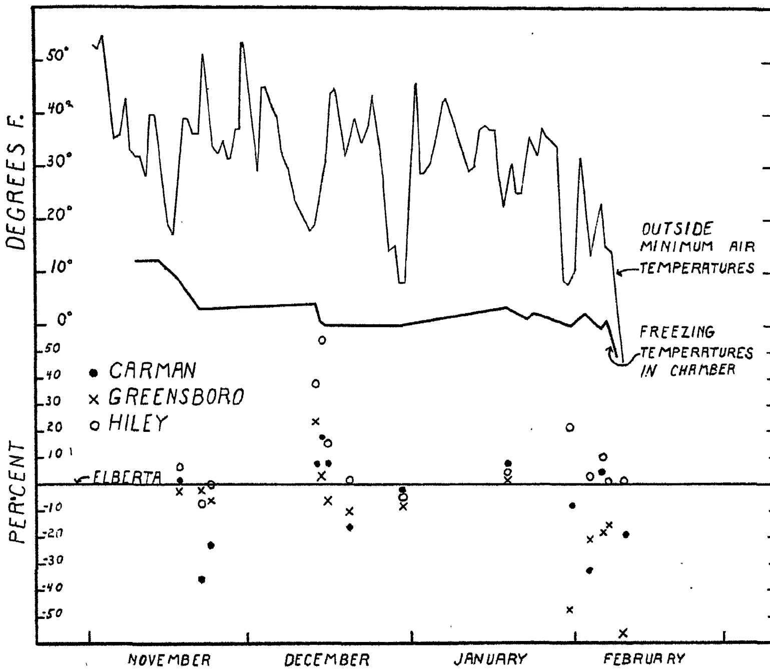

FIG. 2. Percentage of blossom buds of varieties of peach injured at temperatures maintained in freezing chamber during 1933–34 relative to the per cent of injury to Elberta as a base, and with out-door minimum temperatures occurring during period of tests.

their susceptibility to injury at a given temperature, and, secondly, there was a marked varietal difference in the degree of injury observed. Thus, on November 7, Elberta, Belle, Carman, and Greensboro buds from Arlington Farm, Rosslyn, Virginia, showed, respectively, 58, 47, 7, and 13 per cent injury at 14 degrees F, while the same varieties from Beltsville, Maryland, showed 8, 29, 12, and 13 per cent injury. Again, on November 16, at a temperature of 9.5 degrees F, these varieties showed, respectively, for Arlington Farm, Rosslyn, Virginia, 33, 97, 44, and 12 per cent injury, and, for Beltsville, 10, 15, 6, and 2 per cent. (The trees in the Arlington Farm orchard had no nitrogen, little summer cultivation, and had experienced

moisture shortage. The Beltsville trees had been nitrated and were in general in better vigor).

Differences in cold hardiness between varieties was also marked. Early in the season, such hardy varieties as Chili, Greensboro, and Bolivian Cling were injured as severely, or more so, than Elberta and Hiley. This may be due in part to the fact that these varieties bore a full crop in 1934, when buds of all less hardy varieties were killed. Carman, a variety which had a partial crop in 1934, was consistently the most hardy variety all through the fall months. Greensboro developed hardiness by late November and surpassed Elberta. This is also in agreement with results obtained in 1933.

The greater hardiness of buds on qualitatively different shoots was again noted in 1934. On October 18, Elberta buds collected at Warrenton, Virginia, from trees receiving heavy nitrogen applications showed 5 per cent injury, while buds on shoots less vigorous and of small diameter showed 47 per cent injury. Shoots from the same trees on November 19 showed, respectively, 55 and 94 per cent injury at a temperature of 9.5 degrees F. In the same lot, buds from Beltsville showed 27 per cent injury. On November 23, buds collected from an orchard at Crozet, Virginia, about 125 miles south of Washington, and frozen with a lot from trees of similar vigor at Beltsville, Md., showed for the former a range of 0–10 per cent injury for five samples, and for the latter 6–26 per cent for four samples. Although these orchards were widely separated, there was not a marked difference in the amount of injury occurring on this date.

Certain Characteristics of Shoots of All Varieties After Freezing

In the fall, when the peach twigs were subjected to low temperatures, there was severe injury to cambium, outer xylem, and inner cortex, bud scales, and the growing axis of the bud, while the young blossoms enclosed in the bud scales were uninjured. Later, as lower temperatures were reached, and the shoots were more hardened off, the stem tissues were not injured at temperatures which were sufficiently low to kill all of the floral axis. Finally, in later winter, the pistil was killed, while the anthers, sepals and petals were not injured unless the temperature was very low. Browning and discoloration of cells in the stem was noted just back of the growing point. In the early fall it was also noted that there was a great difference in the hardiness of buds on different portions of the twigs. The basal and tip buds were more readily killed at a given temperature than the median buds. The reverse was true in late winter after the rest period was finished. Then the basal buds were less severely injured and the upper middle and tip buds of the shoot were all killed. This is probably due to a difference in rate of development of the basal and tip buds. On shoots 1 foot or more in length the median to tip buds may open 1 to 2 days ahead of the basal buds. This explanation does not hold for the difference in hardiness noted in fall and early winter, because at that time measurements of the length and width of the young blossoms show median buds as large as those near the tip. The basal buds on long vegetative shoots are frequently smaller than those nearer the

middle or tip of the shoot. Furthermore, on long shoots, tip buds may be found which are smaller, depending on the quality of shoot growth and its diameter near the distal end.

The localization of bud injury with reference to position of nodes on the shoots is well illustrated with Greensboro, where 24-to-26-inch shoots were divided into eight sections. The results are summarized in Table I.

TABLE I—PERCENTAGE OF FLOWER BUDS INJURED AT DIFFERENT NODE LEVELS ON SUCCESSIVE SECTIONS FROM BASE TO TIP OF GREENSBORO TWIGS

Portion of Twig	Dec. 19, 1933 0 Degrees F Per cent Alive	Dec. 29, 1933 0 Degrees F Per cent Alive	Feb. 9, 1934* –7 Degrees F Per cent Alive	Feb. 16, 1934 0 Degrees F Per cent Aliv
Basal ⅛	7	99	96	39
	5	97	94	39
	13	98	88	47
	27	100	87	34
Middle⅛	24	100	61	31
	6	100	58	18
	0	100	80	10
Tip ⅛	0	100	82	31

*Temperature minimum occurred in orchard.

It is frequently observed following a severe freeze in late winter that the only surviving buds are on the basal portion of moderately vigorous shoots or short spurs. Not infrequently all the buds on terminal shoots of vigorous trees and on weak spurs will be killed. However, it appears from these studies that there may be variations in amount of injury on qualitatively different shoots. Thus, on January 14, 1932, with buds collected at Beltsville, Maryland, and subjected to a temperature of 5 degrees F, on short spurs 14 per cent of the buds were killed, 3 per cent on long terminals, and 43 per cent on inside slender shoots. On November 15, 1933, 23 per cent of the buds were killed on 2-to-3-foot branched terminals, 12 per cent on 12-to-18-inch terminals, and 43 per cent on short spurs. In the summer of 1933, in an orchard which had been headed back the previous season, it was observed that all the flower buds had been killed on terminal shoots, but many short slender shoots arising from the main branches had blossomed and set fruit. Similar data could be presented showing the differences between the basal, median, and tip portions of vegetative shoots.

That nutritive conditions within the shoot during blossom bud formation may in part be responsible for the differences in survival of buds is suggested in the resistance of buds which were formed on shoots of girdled branches with varying leaf ratios per fruit and subjected to freezing January 12, 1934.

	Per cent dead
10 leaves per fruit	00
20 leaves per fruit	22
30 leaves per fruit	50
40 leaves per fruit	64
60 leaves per fruit	47
80 leaves per fruit	39

Discussion

It is apparent from observations made during the three seasons when fruit buds of the peach were tested, that the amount of injury obtained varies with seasonal conditions, stage of development of the bud, and the qualitative, and perhaps quantitative, conditions existing within the bud itself.

Considerable evidence has been obtained by those working with peach varieties in different sections of the country which shows that hardiness is inherent to a greater degree in some peach varieties than in others. From observations made during this 3-year period it was noted that seasonal growing conditions and size of crop may be an important factor affecting the hardiness of the same varieties. After the rest period has ended, blossom buds of the peach will develop rapidly when temperatures are favorable for growth. Thus, in late winter, the buds which are farthest advanced will be most easily killed by low temperatures. A variety has been observed in the Arlington Farm orchard, S. P. I. 63852, which develops very rapidly after the rest period has been broken. All the buds of this variety were killed by freezes in March, 1932, and in February, 1934, which did little damage to varieties like Greensboro, Carman and Chili. We do not have evidence that this susceptibility to cold is due to an inherent lack of hardiness. In late winter it is probable that certain varieties develop more rapidly after the rest period is over and when favorable temperatures for growth are provided. Thus, Elberta and Hiley, which are two very tender varieties in late winter, seem to develop more rapidly than Greensboro and Chili. Although the difference in actual time of opening of the blossom buds may be but a few days, this may be sufficiently long to affect those conditions within the bud which are responsible for the resistance to cold.

The growing conditions during the early stages of fruit bud initiation and blossom bud development may also be important in determining the resistance to cold in early winter. In the late summer of 1934, the terminal growth of peach trees ceased much earlier in orchards which were dry. The blossom buds in these orchards showed complete development early in September. In early fall bud measurements showed these blossoms to be much larger than those on shoots which continued growth later in the season. With a few of these varieties the rest period was broken and blossoms opened in early November. It has been observed in previous years that although there is considerable difference in the time of initiation of blossom buds on different lengths of shoot growth, there is not such a wide difference in the time of opening in the spring. Recent results by Chandler and Tufts (1) show that blossom buds on the peach will develop very rapidly after the rest period is ended when favorable conditions for growth are provided, and there is very little difference in the time of opening except on some of the more vigorous late-growing shoots. At Fort Valley, Georgia, in the spring of 1932, blossom buds swelled little during the late winter, because of insufficient cold to break the rest period. These buds were not injured at temperatures which caused considerable injury to buds of the same variety farther north which

had been out of the rest period and which were responding to growing temperatures.

In the late winter of 1933–34, a small per cent of fruit buds of the Elberta in an experimental orchard at Beltsville, Maryland, survived a temperature of –10 degrees F, when all buds of the same variety in an experimental orchard only 15 miles farther south were killed at a temperature of –7 degrees F. Buds on trees which were low in nitrogen and where the shoot growth was short did not survive as well as on the more vigorous trees. On the latter, the basal buds of vigorous shoots survived in most cases.

Thus it appears that in addition to variety and stage of development of the bud in early and late winter there are also quantitative and qualitative differences in the shoot growth which may affect the survival of blossom buds during periods of critically low temperatures. Further information is needed to determine what these quantitative differences are and whether or not they can be affected by cultural treatment.

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Cherry Leaf Curl and Root Injury[1]

By L. R. LANGORD, *University of Wisconsin, Madison, Wis.*

A LARGE proportion of the cherry trees growing in the Door County region of northern Wisconsin show a characteristic leaf-curl peculiar to that section of the state. The most outstanding apparent characteristic of the trees affected with this trouble is a curling of the leaves similar to that which might be expected from drought. Associated with the curling of the leaves there is a stunting of growth with an accompanying reduction in productivity.

Soil moisture determinations have shown no consistent differences in soil moisture content between soils on which curl-leaf trees and those on which healthy trees may be growing. Another indication that lack of soil moisture is not the cause of the curling of the leaves is that trees have been observed to first show indications of leaf-curl in the spring, or early summer when there was an abundance of moisture in the soil.

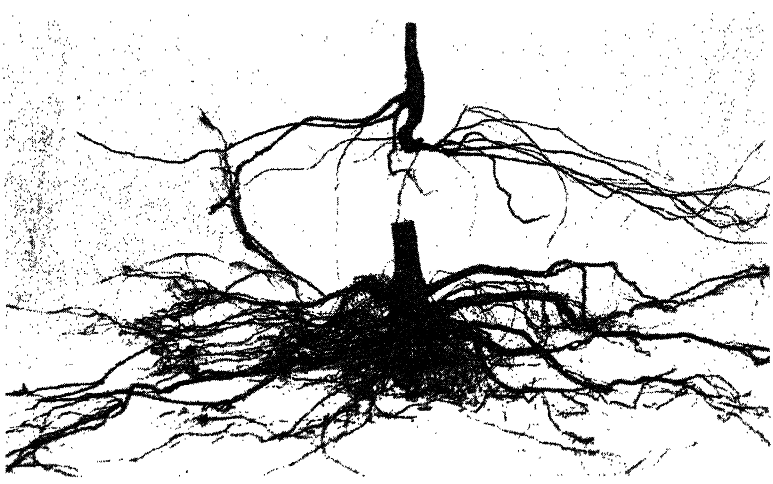

FIG. 1. Typical root systems. "Curl leaf" (upper) and normal (lower) 8-year old Montmorency.

Investigations carried on during the summer of 1933, as well as earlier observations, have shown the leaf-curl to be associated with root injury. Curl-leaf trees were found not only to have a smaller percentage of live feeding roots, but also to have fewer of the larger roots than trees which were normal, Fig. 1. Roots from curl-leaf trees were, in general, of a darker color than those from normal trees.

During the fall of 1933 a number of young curl-leaf trees were mulched with straw over the area which the roots might be expected

[1]Published with the approval of the Director, Wisconsin Agricultural Experiment Station.

to cover. Similar trees which were not mulched served as checks. Some of the check trees were cultivated late in the season to destroy any vegetation which might serve as a mulch. The following summer the mulched trees were found to have less curling of the leaves than the check trees. An examination of the roots of the mulched and non-mulched trees showed the mulched trees to have a larger percentage of live feeding roots than the late cultivated trees. From this it would appear that the root trouble is due to winter injury particularly as most of the feeding roots of the sour cherry are very close to the surface of the soil. Further trials are being made to observe the effects of mulching on root injury.

Characteristics of Diploid and Triploid Apple Varieties I: Measurements of Stomata[1]

By B. R. NEBEL, *Experiment Station, Geneva, N. Y.*

THE presence of diploid and triploid varieties of apples has been known for nearly 10 years (4) but to date not all varieties have been studied for chromosome number and new triploids may still be discovered. About one quarter of all widely grown varieties appear to be triploids. Their value, due to which they have survived selection, must be traceable, since it seems safe to assume that selection has favored triploids during the time of origin of our present day commercial varieties. Their original percentage in chance populations must have been smaller than their numerical presence among our commercial varieties would indicate. Efforts to breed triploids have so far failed. Before these efforts are redoubled it appears advisable to survey the existing triploids for some of their group characters.

At present pollen characters are probably the most reliable indication of triploidy aside from a count of the chromosomes proper. It was also observed that triploid varieties mature their wood relatively late in the fall, and that the general appearance of trees of triploid varieties is coarser than that of diploids. The wood is more spongy and offers less resistance to the pruning shears. Scientific study of the causes underlying these observations is under way, but cooperation is asked, as the field is large and difficult.

The following measurements of stomata (Table I) were gathered in an attempt to collect more knowledge on differential characters in diploid and triploid apples. During July 1934, leaves from 12 triploid

TABLE I—AVERAGE STOMA LENGTH IN μ OF TRIPLOID AND DIPLOID VARIETIES OF APPLES

Triploids		Diploids	
		Ben Davis (2)	62.5
		Cortland‡	58.2
Arkansas (2)*	76.3	Delicious (3)	62.5
Baldwin (2)	72.0	Duchess of Oldenburg (2)	67.7
Fall Pippin†	75.3	Jonathan (3)	62.2
Fallawater (3)	72.0	Macoun (2)	59.8
Gravenstein (2)	73.0	Mann‡	61.2
Holland Pippin†	72.6	McIntosh (2)	63.6
Rhode Island Greening (2)	76.5	Milton‡	61.5
Ribston Pippin (2)	73.2	Northern Spy (1)	61.3
Roxbury Russet (3)	70.3	Northwestern Greening‡	64.5
Stark (3)	76.5	Rome (2)	65.3
Sutton†	73.0	Wealthy§	61.7
Tompkins King (2)	79.0	Yellow Transparent§	65.5
Average	74.14	Average	62.79
Average P. E. of means	±0.747	Average P. E. of means	±0.721

*Numbers refer to the literature cited, giving the original chromosome counts.
†Suspected of triploidy, chromosomes not counted.
‡Suspected of diploidy, chromosomes not counted.
§Nebel, unpublished.

[1]Approved as Journal paper No. 69.

and 14 diploid varieties were collected and the stomata were measured from free hand sections immersed in 3 per cent sugar solution. Table I shows that the triploids without exception have the larger stomata. Each value in Table I is the average of 30–50 individual measurements. The average probable error of the means was close to 1 per cent. It seems safe to claim a 10 per cent difference in average length of stomata between diploid and triploid varieties.

In the course of the investigation it was realized that the length of stomata may vary considerably under various conditions of growth. Stomata from starved trees in pot culture were found to vary as much as 30 per cent from those of normal growing conditions. The measurements contained in Table I are believed to be comparable within the limits of the experiment. Other investigators may find different average absolute values under different conditions. Although the relative values in comparing triploids and diploids should be similar, caution is advised in using stomatal length to decide upon triploidy or diploidy. While this character has been used successfully in detecting polyploidy in maize (5), at present it should be used in the apple only as a preliminary guide.

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Apple Breeding: Inheritance of Tree Shape in Apple Progenies[1]

By H. L. LANTZ and S. J. BOLE, *Iowa State College, Ames, Ia.*

IN 1924 approximately 5,000 crossbred apple seedlings were set in the station orchard at Ames. These were from 55 different crosses, and the number of seedlings varied from six to 352 trees in each of the progenies. Thirty-one varieties were used either as male or female parents. The parent varieties with the largest progenies were Antonovka, Anisim, Ashton, Black Annette, Black Oxford, Colorado Orange, Delicious, Grimes, Harrington, Hubbardston, Jonathan, King David, Nelson Sweet, Northern Spy, Northwestern Greening, Ramsdell Sweet, Salome, White Pippin, and Wealthy. Four of the Patten numbers also were involved, namely, Patten 1000, 1003, 1011 and 1015.

TABLE I—DISTRIBUTION OF SHAPE

Parentage	No. of Trees	Shape Indices										
		Spreading			Round				Upright-spreading			
		.55	.65	.75	.85	.95	1.05	1.15	1.25	1.35	1.45	1.55
Delicious	40	–	—	—	1	7	9	16	4	1	1	1
x Harrington	19	–	—	2	2	1	4	2	1	3	1	1
x Jonathan	17	–	—	—	3	4	—	2	3	1	2	2
x Northern Spy	16	–	—	—	1	—	2	1	1	3	1	2
x Salome	12	–	—	—	—	—	1	1	1	2	4	1
Antonovka x	352	3	7	22	34	62	51	57	50	29	16	8
Anisim x	267	5	18	40	41	45	30	24	26	12	9	6
B. Annette x	94	–	1	3	1	8	7	15	16	9	11	2
Jonathan x	128	–	4	15	17	29	11	16	16	9	8	1
Northern Spy x	264	–	6	13	35	37	23	46	37	27	12	9
N. W. Greening x	99	–	4	4	12	19	14	16	11	5	3	4
Patten 1000 x	35	–	—	—	1	2	1	4	2	5	2	2
Patten 1003 x	27	–	1	4	2	8	2	3	3	1	1	1
Patten 1011 x	52	–	1	4	6	10	8	7	7	4	2	—
Patten 1015 x	59	–	—	—	2	6	4	8	4	15	7	1
Pewaukee x	70	1	—	2	9	12	9	13	10	6	5	1
Subtotal		9	42	109	166	243	167	215	188	131	84	41
Total	1511	160			791				444			
Percentage		10.6			52.3				29.4			

By the fall of 1929 these seedling trees had attained considerable size. The variation in growth characteristics was noticeable, and in particular the habit of growth showed unmistakably the influence of the parent varieties with respect to shape of tree. In connection with other studies, these trees were measured in the fall of 1929 as follows: The height of the tree was measured to the nearest 3-inch in-

[1]Journal Paper No. J225 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 284.

terval from the surface of the soil to the tip of the tallest branch. The spread was measured to the nearest 3-inch interval as the greatest width of branches at right angles to the prevailing wind. Then in order to study the height-diameter relationships, the formula for the height-diameter index, I = (H-2)/D, was used, H being the height of the tree and D the diameter of its spread. Two feet were subtracted from the height in each case, since the trees were headed on the average at about two feet. This ratio is hereafter referred to as the shape index. The shape indices of the seedling trees varied from about 0.50 to 2.50. Those trees with shape indices from 0.51 to 0.80 were called spreading; from 0.81 to 1.20, round; from 1.21 to 1.60,

INDICES IN TREES OF DELICIOUS PROGENIES

Shape Indices									Mean	Standard Deviation	Coefficient of Variability
Upright											
1.65	1.75	1.85	1.95	2.05	2.15	2.25	2.35	2.45			
—	—	—	—	—	—	—	—	—	1.12±0.01	0.14	12.53
1	—	1	—	—	—	—	—	—	1.18±0.04	0.28	23.73
—	—	—	—	—	—	—	—	—	1.16±0.04	0.24	20.65
1	3	—	—	—	1	—	—	—	1.44±0.05	0.32	22.22
1	1	—	—	—	—	—	—	—	1.41±0.04	0.19	13.47
7	1	1	3	1	—	—	—	—	1.11±0.01	0.25	22.29
6	4	1	—	—	—	—	—	—	1.03±0.01	0.30	29.12
6	4	4	2	—	1	2	1	1	1.35±0.02	0.36	26.67
—	—	1	1	—	—	—	—	—	1.04±0.01	0.23	21.82
9	3	3	3	—	1	—	—	—	1.15±0.01	0.28	24.35
2	2	2	1	—	—	—	—	—	1.12±0.02	0.28	25.00
5	1	3	3	1	—	2	—	1	1.55±0.04	0.40	25.81
—	—	—	—	1	—	—	—	—	1.06±0.04	0.31	29.81
1	1	—	1	—	—	—	—	—	1.10±0.02	0.26	23.64
4	3	—	5	—	—	—	—	—	1.34±0.03	0.29	21.64
—	1	—	—	1	—	—	—	—	1.12±0.02	0.24	21.43
43	24	16	19	4	3	4	1	2			
116											
7.7											

upright-spreading; and those 1.61 and above, upright. Trees of a number of the parent varieties were also available for comparative measurements, and these were measured in the same manner to secure their shape indices.

Inheritance of shape of tree was studied with reference to one parent and to both parents. The 55 progenies were classified into nine parent-groups. Each parent-group included all the progenies of a parent variety when used either as a male or female parent.

The distribution of tree shapes in apple seedlings is illustrated by 15 crosses of Delicious. In this group a total of 1,511 seedling trees were measured and their distribution with respect to tree shape is shown in Table I. The mean shape indices of these progenies vary from 1.03 to 1.55. In no case was the mean shape index of a prog-

eny lower than that of the mid-parent. In five progenies it was lower than that of Delicious, it equaled Delicious in three cases and in the other seven cases it was above that of Delicious. In seven progenies the mean shape index is significantly different from their common parent, the Delicious. That round shape is partly dominant seems evident. The regression toward the mean of the race centers at or near the shape index of 1.05, or near the center of measurements for the round shape index.

The dominance of roundish trees is clearly indicated in Table I, which shows 52 per cent of the trees falling into this class. Upright spreading trees constitute approximately 30 per cent of this population, and taken together with roundish account for slightly over 80 per cent of all the seedling tree shapes in these Delicious progenies. Most interesting and remarkable is the occurrence of two modes, one on either side of 1.05. It is evident that inheritance of tree shape is due to a number of genes, which upon recombination produce shapes ranging from spreading to upright, a situation which may possibly be explained by the multiple factor hypothesis. Partial dominance is evidenced by the fact that slightly over half the seedling tree shapes fall within the round-headed class. "Nicking" also seems to operate and when taking place its effect is in the same direction as dominance, i. e., toward a more upright shape of tree. In cases where an individual tree in a progeny or the mean of a progeny has an unusual shape when compared with the shapes of the parents, the "nicking" effect is evidently added to the other effects of inheritance and produces trees which have an average shape much more upright than that of the parents.

In Table II, a total of 3,403 seedlings are classified with reference to the parent variety shapes, such as spreading x round, round x round, round x upright spreading, and upright spreading x upright spreading. That the shape of trees is influenced on the average in the same direction as that of the parent shape is quite evident, as indicated in Table II. These data were tested by the Chi-square test and found to be highly significant and demonstrate that the variations

TABLE II—PARENTS AND THEIR PROGENIES CLASSIFIED AS TO TREE SHAPE

Shape and Indices of Parents	Number of Trees	Spreading (0.51–0.80)	Round (0.81–1.20)	Upright-Spreading (1.21–1.60)	Uprighte (1.61–)
Spreading (.51–.80) x Round (.81–1.20)	1102	192 (17%)	631 (57%)	271 (25%)	8 (1%)
Round (.80–1.20) x Round	1229	173 (14%)	650 (53%)	336 (27%)	70 (6%)
Round (.81–1.20) x Upright-spreading (1.21–1.60)	972	54 (6%)	429 (44%)	370 (38%)	119 (12%)
Upright - spreading (1.21–1.60) x Upright-spreading (1.21–1.60)	100	—	30 (30%)	53 (53%)	17 (17%)

observed in Table II are due to inheritance and not to the errors of random sampling. The phenotype of shape of the parent varieties used in crossing apples is here shown to have some influence on the average shape of the progenies, but it is interesting to note that, in Table III, the mean of a progeny in no case falls below the mean of the more spreading parent variety. There is a constant tendency for the mean of the progeny to be above the mean of the two parents when both are spreading, and to fall between the two parent variety means when one is spreading and the other upright spreading.

To further study the direction of tree shape inheritance, the parent-groups and their progenies were arranged with reference to the shape indices of ten different parents (Table III). The mean shape indices of the common parents are given in column three. The means of the progenies that are lower than the mean of the common parent are in column two; and the means of the progenies that are higher than the mean of the common parent are in column four.

In Table III the first 33 progeny means are clearly seen higher than the means of their respective parents and are in column four. Of the next 34 progeny means, two are equal to the mean of the parent (Delicious), 16 are higher, and 16 are lower. Of the last 12

TABLE III—Parent-groups Arranged with Reference to Shape Indices of Parents and Progenies

1	2	3	4
Indices of Other Parents in Crosses	Mean Progeny Indices Below Common Parent	Mean Index of Common Parent	Mean Progeny Indices Above Common Parent
0.89, 0.99, 0.99, 1.12, 1.12, 1.12, 1.12, 1.39		Jonathan 0.79	0.80, 0.87, 0.93, 1.04, 1.05, 1.09, 1.16, 1.19, 1.45
0.88, 1.12, 1.39		Harrington 0.82	1.08, 1.10, 1.11, 1.18, 1.19, 1.22
0.70, 0.81, 0.87, 1.00, 1.12		Anisim 0.82	0.91, 1.03, 1.04, 1.11, 1.11, 1.13
0.74, 0.82, 1.12, 1.24, 1.24, 1.28, 1.39		N. W. Greening 0.88	1.06, 1.07, 1.11, 1.12, 1.17, 1.24, 1.49
0.79, 1.24		Colorado Orange 0.89	0.93, 0.98, 0.99, 1.10, 1.20
0.79, 0.79, 1.12, 1.39	0.80, 0.87	Salome 0.99	1.05, 1.37
0.70, 0.79, 0.79, 0.81, 0.87, 1.12, 1.24, 1.24	1.04, 1.05, 1.07, 1.07, 1.09, 1.11	Antonovka 1.12	1.27, 1.33
0.79, 0.82, 0.82, 0.88, 0.99, 1.12, 1.39, 1.39	1.03, 1.04, 1.06, 1.10, 1.11	Delicious 1.12 (1.12, 1.12)	1.15, 1.16, 1.18, 1.34, 1.35, 1.41, 1.44, 1.55
0.88, 0.88, 0.89, 1.12, 1.12, 1.28	0.99, 1.06, 1.17	Grimes 1.24	1.27, 1.30, 1.32, 1.33
0.79, 0.82, 0.88, 0.99, 1.12, 1.12	1.04, 1.10, 1.14, 1.14, 1.15, 1.19, 1.24, 1.30, 1.37, 1.37	Northern Spy 1.39	1.44, 1.51

progeny means, two are higher and ten are lower than the means of their common parent, Northern Spy.

The mean shape indices of the ten common parents ranged from 0.79 to 1.39, or from spreading through round to upright-spreading. Each of these parents was crossed with varieties having various shape indices as shown in the second column. If partial dominance were not present, some of the progeny means of Jonathan, Anisim, Northwestern Greening, and Colorado Orange would be likely to be less than the means of their respective parents. The data in Table III, as well as those in Table I, indicate that the round shape of apple tree is partly dominant.

Further evidence that partial dominance operates is indicated in the skewness of the progeny distribution curves. Each of the curves was tested for skewness by means of the formula skewness = (mean-mode)/standard deviation, with the results shown in Table IV. Positive skewness in each of the curves of distribution indicates dominance in the direction of round-headed trees.

TABLE IV—TEST OF PROGENY DISTRIBUTION CURVE

Parent-group or Progeny	(Mean-mode)/S.D.	Sign of Skewness
Colorado Orange	(1.03–0.95)/0.27	+0.30
Delicious	(1.14–0.95)/0.30	+0.63
Northern Spy	(1.20–1.05)/0.28	+0.54
Anisim	(1.05–0.95)/0.27	+0.37
Jonathan	(1.05–0.95)/0.23	+0.44
Harrington	(1.13–1.05)/0.26	+0.31
Antonovka	(1.07–0.95)/0.24	+0.50
Grimes	(1.25–1.15)/0.28	+0.36
Northwestern Greening	(1.16–1.05)/0.29	+0.38
Antonovka x Jonathan	(1.05–0.95)/0.21	+0.47
Antonovka x Black Oxford	(1.07–0.95)/0.24	+0.50
Antonovka x Delicious	(1.11–0.95)/0.25	+0.64
Antonovka x Grimes	(1.30–1.15)/0.26	+0.58

Compilation of Reports on the Relative Susceptibility of Orchard Varieties of Apples to the Cedar-Apple Rust Disease

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THE cedar-apple rust disease is caused by the fungus *Gymnosporangium Juniperi-virginianae* Schw. One phase of this disease occurs on the red cedar and some of its close allies while the other phase occurs on many species as well as on ornamental and orchard varieties, of apples. Observations show that the fungus attacks the eastern red cedar (*Juniperus virginiana*), the western red cedar (*J. scopulorum*) and the creeping cedar (*J. horizontalis.*) All other species appear to be immune. Inoculation experiments conducted in the past few years at the Arnold Arboretum of Harvard University demonstrate that all of the ornamental apples of American origin are susceptible, and that all of the Eurasian apples, except the highly resistant *Malus sylvestris,* and possibly *M. floribunda,* are immune—a finding of much importance with respect to the growing of apples as ornamentals. Many of the varieties of orchard apples are also liable to infection and some of them to such an extent as to result in great economic losses. There are others, however, that seem never to contract the disease.

The disease shows on the cedars as brownish tumors or galls from the size of small peas up to walnut-size. Two years are required for their maturity. The first year is spent in establishing infection and in vegetative growth. In the second spring of their development spore masses in the form of yellow gelatinous tendrils emerge on their surface in wet weather. After the production of a single crop of spores the galls then die and cease to function. Spores from these, however, have already carried the disease to apple trees. The disease on the apples begins to show in June. The leaves chiefly are affected, though on some apples fruits or twigs are also attacked. On the leaves bright yellow spots up to one-fourth inch in diameter are produced. On the lower surface of the leaf, tiny cup-like organs (*aecia*) filled with spores emerge in July. Spores continue to be produced in the aecia during the greater part of the growing season. These spores carry the disease back to the red cedars.

Between extreme susceptibility and strict immunity of orchard varieties of apples there are all intermediate grades. This phenomenon has long been observed and many records of varietal resistance or susceptibility are to be found in the literature. In the present article these scattered reports have been compiled into a single account. The total number of reports on varieties of apples in previous publications has been augmented considerably by reports received in letters from each of the 36 states in which the cedar-apple rust disease is of importance. The whole has been arranged in the table that follows. In such independently conducted surveys one would expect to find considerable variation in the reports on susceptibility, nevertheless, the information conveyed is of great value. The reports on

susceptibility have been interpreted as belonging to one of four categories. These are defined as follows:

Immune—No visible infection spots formed.

Slightly susceptible—Relatively few infection spots, 1 to 5 aecia per sorus; the spots tend to be smaller than average size.

Moderately susceptible—Intermediate number of infection spots, 6 to 15 aecia per sorus; the spots tend to be average in size.

Very susceptible—Large number of infection spots, 16 or more aecia per sorus; these spots tend to be larger than average.

The difference in reports on the susceptibility of any particular variety of apple may be due to one or more of the following reasons:

(a) The relative abundance of the fungus in the year or years that the data were recorded.
(b) The distance of apple trees from cedar trees.
(c) Strains of the cedar-apple rust fungus.
(d) Variation in the susceptibility within a variety of apple.
(e) Incorrect identification of the variety of apple.
(f) The personal element in evaluating relative susceptibility.

In making adjustments for synonymy of the varietal names of orchard apples two publications were used, namely, Ragan (1905) and Beach (1905).

Those varieties of apples which are most frequently reported as immune or slightly susceptible in the following table may be planted with reasonable surety that no severe infection will result on them. The varieties most frequently reported as moderately or very susceptible are liable to severe infections and special precautions must be taken in order to insure satisfactory fruit production.[1]

In preparing the following lists the author is under obligations not only to the numerous contributors of reports found in the literature on the subject but to many personal correspondents. Citations would require almost as much space as the reports themselves.

TABLE I—THE RELATIVE SUSCEPTIBILITY OF ORCHARD VARIETIES OF APPLES TO THE CEDAR-APPLE RUST DISEASE

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Abram	———	Del.	Mo.	———
Ada Red	———	———	———	Ark.
Adel	———	———	———	Iowa
Aiken	———	Ala., Del., Ky.	Ill., Mo.	———
Akin	D. C.	Ala., Del., Ind., Ky.	Del.	———
Alexander	Ky., D. C.	———	N. Y.	———
Allen Choice	———	Iowa	———	———
Aport Orient	Ala.	———	———	———
American Blush	———	Del.	———	———
Ames	———	Iowa	———	———
Anisim	———	Iowa	———	———
Anoka	———	Iowa	———	———
Antonooka	———	Iowa	———	———

[1]For methods of control see Jour. Arnold Arb. 15: 209–223. 1934.

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Arch	Del.	——	——	——
Arkansas	Ala., Del., D. C., Ky., W. Va.	Ala., Del., Ind., Iowa, Miss., Mo., Va., W. Va.	——	——
Arkansas Beauty	——	——	D. C.	——
Arkansas Black	Del., D. C., W. Va., Wis.	Ala., Ind., Iowa, Kan., Ky., Md., N. Y., N. C.	——	——
Astrachan	Ky.	——	——	——
Babbitt	D. C.	Ala.	——	——
Bailey Sweet	——	——	Iowa	——
Baldwin	D. C., Ky., W. Va., Wis.	Conn., Del., Ind., Iowa, Mass., N. H., Pa., R.I., W.Va.	N. Y.	N. J.
Banks Red Gravenstein	——	Iowa	——	——
Barry	——	——	——	D. C.
Bayard	——	——	Ky., N. Y.	——
Bayfield	——	——	——	Iowa
Baxter	——	——	N. Y.	——
Beach	Ala.	——	——	——
Beauty	Iowa	——	——	——
Bechtel's Crab	——	——	——	Conn., Del., Iowa, Kan., Mass., Neb., N. Y., Va., Wis.
Belle et Bonne	——	——	Ky., S. C.	——
Ben Davis	Ky.	Del., D. C., Iowa, Mass., Neb., Ohio, R. I., Tenn., Va., W. Va.	Ala., Ark., Ill., Ind., Iowa, Mo., N.Y., N.C., Pa., Tenn., W. Va.	Va.
Benoni	——	——	Ala.	Idaho, Ill., Iowa, Ky., Mo., W.Va.
Bietigheimer	Del., Ind.	Ala., D. C.	——	——
Black Ben Davis	Ky.	Ala.	——	——
Black Buda	Ala.	——	——	——
Black Gilliflower	——	——	Mass., N.Y.	——
Black Lady	Del.	Ala., Va., W. Va.	Mo.	——
Bledsoe	——	Ala.	——	——
Blythe	——	——	——	Ky.
Boiken	——	Iowa	——	N. Y.
Bonum	Ky.	——	——	Del., N. C., Va.
Bostick	——	——	——	Del.
Bough	——	Iowa	——	——
Bradford	——	Ala.	——	——
Buckingham	D. C., Ky.	Minn., N. C.	——	Ala.
Buncomb	Del.	Ala.	——	——
Burt	——	——	——	Del.

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Canada Baldwin		Iowa		
Cannon		Ala.		
Carlough				Del.
Carolina Beauty		Del.		
Carolina Greening				Ala.
Carpetin				Del.
Carter's Blue				Ala., Del.
Cathay		Iowa		
Celestia	Ala., Ky.			
Charlemoff	Ky.			
Chattahoochee				Ala.
Cheese	Ky.			
Chenago	Ky.	Iowa		
Chester White		Iowa		
Chicago		W. Va.		
Cillagoes		Ala.		
Clayton				Del.
Collins	Ala., D. C., Iowa, Ky.			
Cooper Early		Neb.		
Cortland		Iowa		
Cowgill	Del.			
Cox Orange			Ky., Iowa	
Crawford		Del.		
Dam		Ala.		
Daniel's Red Duchess		Iowa		
Dartmouth	Ky.			
Delicious	Ky., Minn., N. C., W. Va.	Ill., Ind., Iowa, Mo., N. H., Tenn.	Mass., N. J.	
Detroit Red	Ind.			
Doctor Matthews			Ind.	
Doctor Walker				Del.
Doctor Van Fleet	Iowa			
Dolgo		Iowa		
Domine	Ky.	W. Va.	Ind., Iowa	
Drap d'or		Del.		
Du Bois		Ill., Iowa, Minn., Mo., Neb., N. C., Tenn.		
Dudley			Iowa	Wis.
Early Chandler	Del. Ky.			
Early Golden Russet			Iowa	
Early Harvest	Del., D. C., Ky., Mo.	Ala., Iowa, Neb., Tenn., W. Va.	Kan.	
Early Joe		Iowa		
Early Lippincott	Del.			
Early McIntosh		Iowa		
Early Melon		Ky.		
Early Pinnock	Ala.			
Early Ripe			D. C.	
Early Strawberry	Ky.		Iowa	
Edgewood				Iowa
Elgin Pippin		Ala.	Ky., Minn.	
English Russet			Ind., Ky., N. J.	Ala.

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Epic	Ala.	—	—	—
Erickson	—	—	Iowa	—
Esopus	D. C.	Iowa	Mass.	Ky., N. Y.
Excelsior	Ky., N. Y.	—	Ind.	—
Fallawater	—	—	Ky.	Conn., Del., Iowa, N. J., N. C., Pa.
Fall Beauty	—	—	Ky.	—
Fall Pippin	Ala., Del., D. C., Ky.	Iowa	—	—
Fall Wine	Ky.	—	Ind.	—
Fall's Favorite	Del.	—	—	—
Fameuse	W. Va.	Iowa, Wis.	—	Md.
Family	—	—	—	Ala.
Fanny	Ala., Ky.	—	Ind.	—
Florence	D. C., Ky.	Iowa	—	—
Flory	—	—	D. C.	D. C.
Folwell	—	—	Minn.	—
Fondville	Del.	—	—	—
Four Belleflower	—	—	—	Del.
Gano	Ala., D. C., Ky.	Del., Iowa, Kan., Neb., N. C.	Ill., Mo.	—
Genessee Flower	—	Ind., Neb.	—	—
General Grant	—	Iowa	—	—
Giant Geniton	Ky.	—	—	—
Gideon	—	Iowa	D. C., Ill., Mo.	—
Gilbert Winesap	Ky.	—	—	—
Gilpin	—	—	—	Del.
Gladstone	—	—	D. C.	—
Gloria Mondi	Del.	—	—	—
Gold (Crab)	Ky.	—	—	—
Golden Délicious	—	Ky., Iowa, S. C.	Ark., Neb., N.C., Tenn.	—
Golden Pippin	Del.	—	—	—
Golden Russet	D. C., Ind., Ky.	—	Iowa	Del.
Golden Sweet	Ky.	—	Iowa	—
Golden Winesap	—	Iowa, Ky.	—	—
Goldo	—	—	—	Iowa
Gravenstein	Ala., Del., Ky., W.Va.	Ala., Iowa, Mass., N. H., N. Y.	—	—
Great Mogul	—	—	—	Vt.
Grimes	—	Ala., Conn., D. C., Ill., Ind., Iowa, Ky., Va., W. Va.	Ala., Ark., Ind., Kan., Iowa, Mo., Neb., Pa., Tenn., Va.	Del., Iowa S. C.
Hackworth	Ky.	—	—	—
Haglow	Del	—	—	—
Hands	—	Ala.	—	—
Hargrove	Del.	—	—	—
Harolson	—	Iowa, Minn.	—	—
Haughley	Del.	—	—	—
Hawkeye Greening	—	Iowa	—	—
Haygood	—	—	—	Ala.

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Haywood	———	———	———	Del.
Henis Crab	Ala.	———	———	———
Henry Clay	Ky.	———	———	———
Hershall Cox	Ala.	———	———	———
Hibernal	Minn.	Ind., Iowa, Minn.	———	———
Hightop June	———	———	———	Iowa
Hislop	Ky.	Iowa	Ind.	———
Holland Pippin	Del.	———	———	———
Homing	———	Kan.	———	———
Hoover	———	———	N. C.	———
Hopa	———	Iowa	———	———
Horse	———	———	Tenn.	N. C.
Hubbardston	D. C.	Iowa	Ky., N. Y.	———
Huntsman	Ind., Ky., Mo.	Iowa	———	———
Hurlbut	———	———	———	Conn.
Hyari Piros	Ala.	———	———	———
Hyde King	Ky.	———	———	———
Imperial Rambo	———	———	Ky.	———
Ingram	Ky.	Iowa, W. Va.	———	———
Iowa Blush	———	———	Ind., Neb.	Iowa
Jackson	———	———	———	Del.
Jacobs Sweet	Ind.	———	———	———
Jefferis	Ky., N. C.	———	———	———
Jefferson County	Ala., Ind.	———	———	———
Jeffries Everbearing	———	Ala.	———	———
Jewett Red	———	———	———	Del.
Jonathan	———	Iowa	D. C., Ky., Minn., N.C., Tenn., Wis.	Ala., Ark., Conn., Ill., Ind., Iowa, Kan., Ky., Mo., Neb., N. Y., Ohio, Pa., Tenn., Va., W.Va.
Jones Cider	———	———	———	Del.
Julian	———	———	———	Ala.
July	———	Del.	———	———
Jumbo	———	Iowa	———	———
Kees Kemet	———	Ala.	———	———
King	———	Iowa	Mass., Conn.	———
King David	Ky., W.Va.	Iowa, Tenn.	Ind., N. C.	———
Kinnard	Ala., Del., Ky.	Ala., Ind., Tenn.	———	———
Kinnard McIntosh	W. Va.	———	———	———
Kiswick	Ky.	Del.	———	———
Knowles Early	Del.	———	———	———
Lacker	———	———	Ky.	———
Lanber	———	Del.	———	———
Lancingburg	Ky.	———	———	———
Langford	———	Del.	———	———
Lanier	———	———	———	Del.
Lankford	———	———	———	Del.
Large Red Romanite	———	———	———	Iowa
Late Strawberry	———	———	Iowa	———

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Lawver	D. C., Ind., N. C.	———	———	———
Lewis	———	———	Ky.	———
Lilly of Kent	———	Del.	Ky.	———
Limbertwig	Del., Ky.	Ala.	———	———
Lindenwald	Ky.	———	Tenn.	———
Livland Raspberry	Ky.	———	———	———
Lobb	———	Iowa	———	———
Longfield	Iowa	Iowa	———	———
Lowell	Ky.	Iowa	———	———
Lowland Raspberry	———	Iowa	———	———
Lowry	Ky.	———	———	———
Magenta	———	———	N. C.	Del.
Maggar	Ala.	———	———	———
Magnate	N. C.	———	———	———
Magnet	———	Iowa	———	———
Maiden Blush	Ala., Ind.	Iowa, Neb., N. C.	D. C.	———
Maiden Favorite	Ind., Ky.	Ala., Del., Mo., Neb., Pa., W. Va.	Ark.	Md.
Malinda	Ala., Ky.	Iowa, Neb., Va.	———	———
Mangum	———	———	———	Ala.
Mann	Del., Ky., Iowa, W.Va.	———	———	———
Marita	———	———	———	Ky.
Martha	———	Iowa, W.Va.	———	———
Marvina	———	———	———	Ala.
Maryland Blush	———	———	———	Del.
Matthew's Crab	———	———	———	Mass.
Mavarack	———	Ala.	———	———
Mercer County	Iowa	———	———	———
Milam	Ky.	———	———	———
Milwaukee	Ind.	Iowa	———	———
Minkler	———	———	———	Del., Ill., Ind., Iowa, Ky., Mo.
Minnehaha	———	Iowa	———	———
Minnesota	———	Iowa	———	———
Missouri Pippin	———	Ky.	———	Del., Ind., Iowa, Neb.
Mitchell	Ala.	———	———	———
Monona	———	Iowa	———	———
Mother	D. C.	———	———	Ky.
Moultiers	———	———	———	Ala.
McAfee	Del.	———	———	———
McIntosh	D. C., Ky.	Conn., Iowa, Mass., Minn., N.H., N.Y., Wis.	———	———
McMahon	———	Ind., Iowa, Wis.	———	———
Nero	———	———	D. C.	Del., Ky.
Newtown	———	———	N. Y.	———
Newtown Pippin	Del., D. C.	———	———	———

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
New Water	Del.	———	———	———
New Zealand Spy	———	Ky.	———	———
Nickajack	———	———	———	Ala., Del., Va.
Niedwetzkyana	Iowa, Mass.	———	———	———
Noble Savor	Ala.	———	———	———
Northern Spy	———	D. C., Ind., Iowa, Ky., Mass., Pa.	Va.	D. C., Va.
Northwestern Greening	Ind., Ky., W. Va.	Conn., Ill., Iowa, Minn., Mo., Neb., Va., Vt., Wis.	N. Y., Va., W. Va.	———
Okabena	Minn.	Iowa	———	———
Oldenburg	Iowa, Ky., Minn.	Ind., Iowa, Kan., Neb., N. Y.	———	———
Olga	Iowa	———	———	———
Oliver	———	Va.	Ark.	Ala., D. C., Ky.
Ontario	———	———	Iowa	———
Opalescent	———	———	Ky., N. Y., Iowa	———
Ortley	Ky.	———	———	———
Oszi	———	Ala.	———	———
Ozone	———	D. C.	———	———
Paducah	———	Ky.	———	———
Palmer	———	———	Ind.	———
Paradise Sweet	———	———	Ky.	———
Paragon	Del., D. C., Ky.	Iowa, N. C., Pa., Tenn., W. Va.	———	———
Pasman	Ala.	———	———	———
Patten	Miss.	———	Iowa	———
Payne	———	———	———	Mo.
Pear (Palmer)	———	Ala.	———	———
Pease	Ind.	———	———	———
Peerless	———	———	Iowa	———
Peerless Sweet	———	———	———	Wis.
Perkins	———	Iowa	———	———
Peter	Del.	———	D. C., Ind.	Iowa
Pewaukee	D. C.	Ind., Ky.	———	———
Piper's Fall Beauty	———	———	Ky.	———
Plum Cider	———	———	———	Wis.
Ponjik	Ala.	———	———	———
Porter	Ky.	———	———	———
Pound Sweet	———	Iowa	———	———
Prairie Crab	———	———	———	Iowa, Mass., Mo., Neb., N. Y.
Price Sweet	———	———	Iowa	———
Primate	Ky.	———	———	———
Pryor	———	———	———	Ky.
Quaker Beauty	———	———	———	R. I.
Ralls	Del., Mo.	Ala., Iowa, Ky., Neb.	———	———

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Rambo	———	Iowa	D. C., Ind., Ky., Pa.	Pa.
Ramsdell Sweet	———	Iowa	———	———
Raspberry	Del.	———	———	———
Red Astrachan	Ala., Del., D. C.	Ala., Ind., Iowa, Md., Mass., Neb., N.Y., R.I., W.Va.	———	———
Red Cain	———	Del.	———	———
Red Canada	D. C., Ky.	———	———	Iowa
Red Delicious	———	Mass., Neb., N. C.	———	———
Red Duchess	———	Iowa	———	———
Red June	———	Ky., N. Y.	Iowa, Tenn.	Ala., Del., Ill., Iowa, Ind., Mo., Neb., N. C., S. C.
Red Limbertwig	———	———	N. C.	———
Red Northern Spy	———	Iowa	———	———
Red Siberian	———	———	———	Iowa
Red Tip	———	———	Iowa	———
Red Vein	Iowa	———	———	———
Red Winesap	———	S. C.	———	———
Red Wing	———	———	Iowa	———
Reid's Early	Ky.	———	———	———
Rhode Island	Ky.	Del., N. Y.	Ind., Conn.	———
Rhode Island Greening	———	Iowa	———	———
Rhodes Orange	———	———	———	Ala., Del.
Richard	———	Iowa	———	———
Romanite	———	———	———	Ky.
Roman Stem	———	Ky.	Iowa	Del.
Rome	———	———	Mass., N. J.	Ala., Del., Ill., Ind., Iowa, Kan., Ky., Md., Minn., Mo., N.Y., N.C., Ohio, Pa., Tenn., Va., W. Va.
Ronk	———	———	Ind.	———
Roxbury	Ky.	Iowa	———	N. Y.
Sabadka	Ala.	———	———	———
Saint Lawrence	———	Iowa	———	———
Salome	D. C., Ky.	N. C.	N. Y., Iowa	———
Santa Movalolybi	———	———	———	Ala.
Saxon Priest	Ala.	———	———	———
Scarlet Cranberry	———	———	———	Del.
Scott Best	———	———	———	Ind., Iowa
Scribner	———	———	———	Ala., Ky.
Secor	———	———	Iowa	———
Seedling	Ala.	———	———	———
Sekula	———	Ala.	———	———
Selomes	Ala.	———	———	———
Shackleford	Ala.	———	D. C.	———
Shannon	D. C.	———	———	Del.

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Sharon	———	Iowa	———	———
Shiawassee	———	———	D. C.	———
Shields	———	Iowa	———	———
Shockley	———	———	Ala.	Del., N. C., S. C.
Silver	Iowa	———	———	———
Simmons Red	———	———	———	Del.
Smith Cider	Del., Ky.	———	———	Ill., Mo., Va.
Smokehouse	———	———	Ky., N. J., Pa., Iowa	Del.
Soulard Crab	———	———	———	Conn., Iowa, Mass., N.Y.
Springdale	———	———	Ind.	———
Stanard	———	———	D. C.	———
Stark	———	Iowa, Pa.	Ky., Ind., Mass., N.Y.	Del.
Starking	W. Va.	———	———	———
Stark's Delicious	———	Pa., S. C.	———	———
Starr	Del. Ky., W. Va.	Ind., Mo., N. C., Pa., S.C., Tenn., Va.	N. J.	———
Stayman	Del., W.Va.	Ark., Iowa, Kan., Mo., N. C., Tenn., Va.	Ind.	———
Stayman Winesap	Del., D. C., Ky., Va., W. Va.	Ind., Md., Minn., N. C., Pa., Va.	Pa.	———
Stowe	Del., Ky.	———	———	———
Success	———	Iowa	———	———
Sugar	———	———	———	Iowa
Summer	———	Ala.	———	———
Summer Cheese	Ala.	———	———	———
Summer Hagloe	Del.	———	———	———
Summer Pearmain	———	Ky.	———	Del.
Summer Queen	Ala., Del.	———	———	———
Summer Rambo	Ind.	———	———	———
Summer Wafer	———	Ala.	———	———
Sutton	———	D. C., Ky., Mass.	N. Y.	———
Sweet Bough	Del., Ky.	Ala., W.Va.	———	———
Sweet Bellflower	———	———	———	Ind.
Sweet Greening	———	Neb.	Ind.	———
Sweet Russet	———	———	Iowa	Va.
Sylvester	———	———	———	Del.
Taunton	Del.	Ala.	———	———
Terry	———	S. C.	Ga.	———
Tetofsky	D. C., Ind., Iowa	Iowa	———	———
Texas Red	———	Ala.	———	———
Tolman	———	Ind., Iowa, Kan., Wis.	N. Y., Va., W. Va.,	———
Tompkins King	D. C.	———	N. Y., Iowa	———
Transcendent	Ky.	Iowa	———	———

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Turkey	———	Iowa	———	———
Twenty Ounce	D. C.	Del.	Mass.	N. Y., Vt., Iowa
Two Large Red	———	———	———	Del.
University	———	Iowa	———	———
Utter	———	Iowa	———	———
Vandevere	D. C.	———	———	———
Vanhoy	———	———	D. C.	———
Virginia	———	Iowa	———	———
Virginia Beauty	Ky.	Neb.	———	———
W. Twig	Ky.	———	———	———
Wagener	D. C., Del., Ky.	Iowa	Ind., Mass.	———
Walbridge	Ind., Ky.	———	———	———
Wealthy	———	———	N. J., N. C., Tenn.	Conn., Ill., Ind., Iowa, Kan., Ky., Md., Mass., Minn., Mo., Neb., N. H., N. Y., Ohio, Pa., R. I., Tenn., Va., Vt., W. Va., Wis.
Weisner	Ky.	———	———	———
Westfield	Ind.	Iowa, W. Va.	———	———
Western Romanite	———	———	———	Del.
White Pearmain	———	Iowa, Ky.	———	———
White Pippin	Ky.	———	D. C., Ind.	———
White Spanish	Del.	———	———	———
Whiting	———	———	N. C.	———
Whitney	Ky.	———	Neb., Wis.	Iowa
Williams	Ky.	N. C.	———	———
Willow	———	———	Iowa	———
Wilson's Red June	———	Ky.	S. C.	———
Windsor	Ky.	———	———	———
Windsor Chief	———	Iowa	———	———
Winesap	Ala., Del., D. C., Ky., Va., W. Va.	Ala., Ark., Ill., Ind., Iowa, Kan., Md., Minn., Mo., Neb., N. C., Pa., S.C., Tenn., Va., W. Va.	———	———
Winter Banana	———	———	Ind., Iowa, Ky., N. J., Tenn.	D.C., Mass., N. Y.
Winter Brown	Del.	———	———	———
Winter Gricksome	Del.	———	———	———
Winter Pearmain	———	Ala.	———	———
Winter Sweet Paradise	———	———	Iowa	———
Wisconsin Russet	———	Iowa	———	———
Wolf River	Ind., Ky., Minn., W. Va.	Iowa	———	———
Yakor	Ala.	———	———	———

TABLE I—*Continued*

Variety	Immune	Slightly Susceptible	Moderately Susceptible	Very Susceptible
Yates	———	Del., S. C., Wis.	———	———
Yellow Bellflower	D. C., Ky.	———	Ind., Miss., Mo., Wis.	Iowa
Yellow Horse	———	———	Ky.	———
Yellow Newtown	Ky.	Iowa, Va.	———	Del.
Yellow Red	———	Ala.	———	———
Yellow Siberian	———	Iowa	———	———
Yellow Transparent	Del., D. C., Ky., W.Va.	Ill., Ind., Iowa, Kan., Md., Mass., Mo., Neb., N. Y., Pa., R. I., Tenn., W.Va., Wis.	Ark.	———
Yopp	———	———	———	Ala.
York	———	Ind., Kan., Md.	Mo., Neb., N. C., Pa., W. Va.	———
York Imperial	———	Ala., Iowa, Kan., Ky., Neb., Wis.	Ala., D. C., Mo., N. C.	Del., D. C., Ill., Md., Pa., Tenn., Va., W. Va.

Trunk Growth and the Water Relation in Leaves of Citrus

By F. F. HALMA, *Citrus Experiment Station, Riverside, Calif.*

IN a previous report (1), it was pointed out that during the growing season the weekly growth increment of Citrus fruits tends to follow the same general direction as the weekly soil moisture curve, and that the "relative saturation deficit" in the leaves shows an inverse trend. The term "relative saturation deficit", (R. S. D.), as previously explained (1) designates the difference (in per cent of the weight at saturation) between the weight of freshly picked leaves and that obtained after artificial saturation.

Recently, Oppenheimer and Mendel (2) determined what they designate as the "water saturation deficit" in Citrus leaves. They used Stocker's (3) formula, which may be expressed as,

$$W = \frac{\text{Maximum water content—Water content in Nature}}{\text{Maximum water content}} \times 100,$$

the maximum water content being the difference between weight at saturation, and that after drying the plant tissue at 105 degrees C. Higher values are obtained by this method than by the one used in the present investigation, but the nature of the two curves is practically the same.

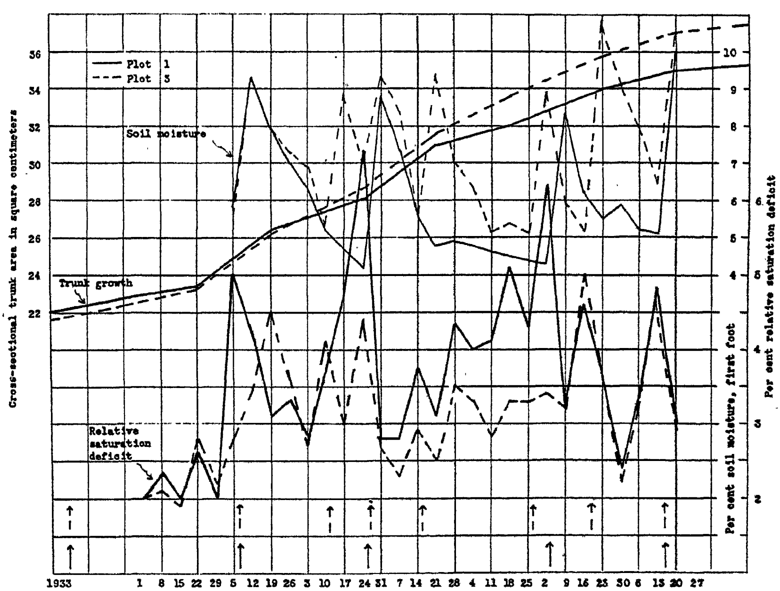

FIG. 1. Relative saturation deficit of Navel orange leaves in relation to growth. Arrows indicate date of irrigation.

In view of the importance of water in photosynthesis, it was thought desirable to investigate the R. S. D. in leaves in relation to tree growth under orchard conditions. The present report deals with data obtained during the 1933 and 1934 seasons in a Washington Navel orange orchard located at the Citrus Experiment Station, Riverside, California.

The orchard, planted in the spring of 1930, consists of budded trees on sweet-orange and sour-orange rootstock in alternate rows. In the spring of 1933, a tract of 5 acres was divided into four equal plots, each consisting of 12 rows with 10 trees in each row. Only the trees on sweet-orange rootstock, a total of 60 trees per plot, are dealt with in this report. These bore a light crop of fruit in 1933; in 1934 yield records are not yet available.

In two of the plots an attempt was made to bring about a condition in which the R. S. D. was to be allowed to reach a definite peak before water was applied, while in the other two plots the R. S. D. was to be maintained at a lower level.

At each weekly sampling, one healthy mature leaf was taken at 10:30 a.m., and again at 1:30 p.m. from the shady side of the 5th, 6th, 7th and 8th trees in one row. After several weeks the sampling was shifted to another row. Only two rows were used during the season, and the total number of leaves taken from any one tree did not exceed 30. In the same two rows the tree trunks were measured every month omitting the 1st and 10th trees in each row. At each irrigation, water was applied in three straight furrows on each side of the tree

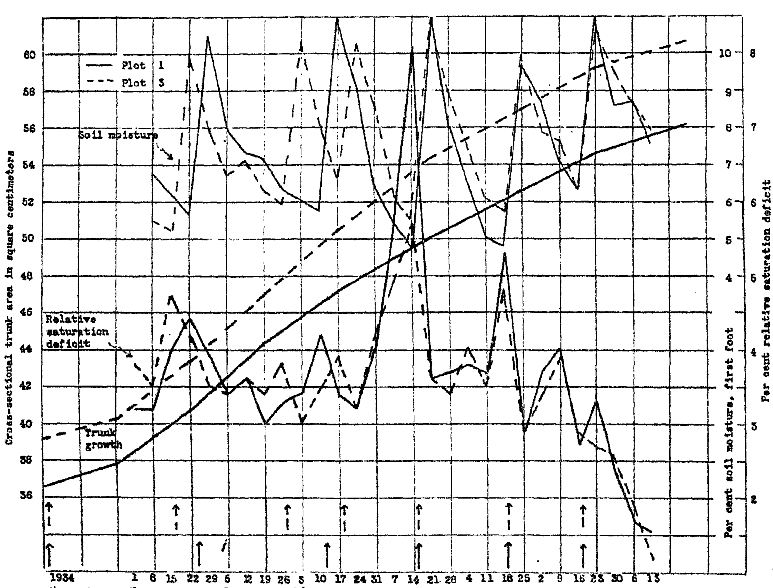

FIG. 2. Relative saturation deficit of Navel orange leaves in relation to trunk growth. Arrows indicate date of irrigation.

row and kept running until a 3-foot penetration was secured. It should be mentioned in this connection, however, that although the irrigation run was only 180 feet, the trees in the lower part of the run were generally the first to show symptoms of lack of water.

The data obtained during the two seasons were consistent in the two sets of plots, hence it is only necessary to present the data of one of the sets, which will be referred to as plots 1 and 3. Figs. 1 and 2 show the weekly average of the R. S. D. of the combined 10:30 a.m. and 1:30 p.m. leaf samples (a total of eight leaves), in relation to the monthly average cross-sectional trunk area of 16 trees.

During the 1933 season (Fig. 1), the R. S. D. in plot 1 showed three distinct peaks, and during August and September the values fluctuated on a higher level than those for plot 3. Different degrees of wilt, more pronounced in the lower part of the rows, were observed in plot 1 on July 24 and October 2. It was also observed that the summer growth in plot 1 was not only delayed but that at maturity the leaves were smaller than in plot 3.

In regard to trunk growth, Fig. 1 shows that the rate for both plots was similar until July. From then on the curves showed an increased divergence as the season progressed. Between March 1933, and March 1934, the average increase in square centimeters of the cross-sectional trunk area amounted to 14.5 for plot 1, and 17.5 for plot 3, a difference of 3.0 in favor of plot 3.

During the 1934 season (Fig. 2), the highest R. S. D. for plot 1 was recorded on August 14. This was accompanied by a decided wilt during the greater part of the day. A slight wilt was observed in the lower part of the rows on September 18. The relatively high peak in plot 3 on August 14 was caused by a delay in obtaining irrigation water. A slight wilt was observed about midday. The effect on summer growth and on leaf size in plot 1 was again evident.

The point of interest in the trunk growth during 1934 is the fact that plot 3 began to forge ahead of plot 1 during July or about four weeks before the R. S. D. in plot 1 reached the high peak. This indicates a hold-over effect from the 1933 season. Between March and November 1934, the increase in cross-sectional area in square centimeters amounted to 19.6 for plot 1, and 21.5 for plot 3, a difference of 1.9 in favor of plot 3. The total difference for the two seasons was 4.9.

The soil moisture records plotted in figures 1 and 2 were obtained by the Division of Irrigation Investigations and Practice. They represent average values of 4 samples taken in the first foot of soil near two trees, but not in the same rows from which leaves were taken. In the second foot of soil, the moisture was always above the wilting point, which is approximately 4.7 per cent. During the 1933 season light rains occurred on June 5, August 24, September 29, and October 31, and during 1934 on October 5, and a fairly heavy rainfall on October 18 and November 16 and 19.

It may be of interest to mention the range in air temperature and relative humidity observed at the time the leaves were collected. Between June and October 1933, the minimum air temperature was 58 degrees F at 10:30 a.m. on June 5, and the maximum 106 degrees

at 1:30 p.m. on July 24. The minimum relative humidity was 13 per cent at 1:30 p.m. on July 10, and the maximum 87 per cent at 10:30 a.m. on September 25. During the same period in 1934, the minimum air temperature was 61 degrees F at 10:30 a.m. on June 5, and the maximum 104 degrees at 1:30 p.m. on July10. The minimum relative humidity was 14 per cent at 10:30 a.m. on July 10, and the maximum was 73 per cent at 10:30 a.m. on June 5. The soil temperature at 18 inches ranged from 60 to 82 degrees F in 1933, and from 72 to 84 degrees F in 1934.

The most severe conditions, however, to which the trees were subjected during the two seasons occurred on July 27, 1934, which was not a regular sampling date. On that day, the temperature rose to 117 degrees F accompanied by puffs of hot wind. The relative humidity was 14 per cent. Special determinations of the R. S. D. gave average values of 4.84 per cent for plot 1, and 4.67 per cent for plot 3. It is evident from Fig. 2 that the effect of this extremely high temperature on the water balance in the leaves was insignificant in comparison with that produced by lack of available water on August 14.

In conclusion, it should be emphasized that the data given in this report were obtained under two irrigation treatments, both of which fall well within the range of commercial practices under interior conditions of southern California. The results are indicative of the importance of maintaining a relatively favorable water balance in the leaves. As to yield of fruit, no reliable data will be available until the trees are of bearing age. Fruit growth studies carried on during the two seasons showed that, although a temporary lag of fruit-growth increment occurred when the R. S. D. was high, the final size of the fruit was practically the same in both plots.

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Absorption of Water by the Foliage of Some Common Fruit Species[1]

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THE root is commonly regarded as the principal water absorbing organ of plants. The possibility that other organs, particularly the leaves, may be concerned with the absorption of water usually has been given little consideration. Wetzel (5), however, from his study of over 100 different plants, showed that wilted leaves were able to absorb water, but not as rapidly as roots. He observed wide differences between plants of the same genus and species in their ability to absorb water through the leaves. He found that absorption depended upon the ability of the cuticle to become wetted; that in most cases the lower surface absorbed water more rapidly than the upper; that water was not absorbed through the stomates except under abnormal conditions and that the amount of water conducted away from the leaves is very small. He concluded that the ability of wilted leaves to absorb water is a common phenomenon but that the biological significance of this is undetermined.

Kessler (4) found in his recent studies that wilted leaves of certain genera including Vitis, Lactuca, and Solanum, increased in weight when floated so that only the upper surfaces were in contact with the water. He also found that wilted leaves of Beta, Lycopersicum, Phaseolus, Solanum, Cucumis, Vitis, Rubus and others increased in weight when sprayed with water. He concluded that many plants take up water through the leaves and that the intake was influenced by factors such as permeability of the cuticle and epidermis, the ease of wetting and hairiness of the upper surface, and the osmotic pressure of the parenchyma cells bordering on the epidermis.

Grundmann (3) wilted potted plants of Solanum, Lycopersicum, and Trifolium and was able to restore turgidity by placing the plants in a specially constructed double-walled chamber and repeatedly obtaining condensation of moisture upon the foliage by manipulation of humidity and temperature.

The writer, in a previous study (1) of the effects of pruning upon the behavior of the Latham raspberry, noted an increase in the size of berries following very light showers. Observations made at that time showed that the foliage had been wetted by the showers but not enough rain had fallen to wet the soil beneath the plants and barely enough to wet the surface elsewhere. It seemed likely that the increase in size of berries following such light showers might be due in part to the absorption of water by the leaves although the effect of the showers on air temperature and transpiration were not overlooked. Soon after this, Darrow and Sherwood (2) found that the leaves of wilted strawberry plants when immersed were able to absorb enough water to regain turgidity. The possibility suggested by these reports, that the leaves may contribute frequently to the water intake of fruit plants, led to the present studies. Although this study was undertaken

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primarily to observe the behavior of certain representatives of the genus Rubus, it was broadened to include a total of 15 genera, 35 species, and 51 horticultural varieties or seedlings.

Material and Method

For the major portion of these studies, a procedure was followed that was similar in many respects to the method used by Wetzel. Shoots were cut in the field and placed immediately in a jar of water to avoid wilting. They were taken at once to the laboratory where normal uninjured leaves were cut from the shoots, the cut ends of the petioles sealed with paraffin, and the sample weighed. The number of leaves used depended somewhat upon their size, but in most cases 20 leaves were used. Each sample was made up of entire leaves except in the case of *Carya ovata* in which only the large terminal leaflets were used. After they were weighed the leaves were spread out in the laboratory and allowed to wilt until limp and then weighed again to note the loss in weight. The time taken for wilting varied with the species, variety, and atmospheric humidity, ranging from a few minutes to an hour and a half. With some species such as *Prunus cerasus* and *Carya ovata* the firm texture of the leaves made wilting difficult to detect. In such cases the leaf samples were dried until the loss of weight was considered equivalent to wilting. In all cases the degree of wilting was more severe than would ordinarily occur in the field under drouth conditions. As wilting was more rapid in some species than in others, no attempt was made to obtain uniformity in the per cent of weight lost. The loss of weight ranged from 3.4 per cent in *Carya cordiformis* to 15 per cent in one sample of *Rubus strigosus* not included in the accompanying table.

Each sample of wilted leaves was quickly attached by the petioles to the periphery of a large flat cork by means of a rubber band so that the sealed ends of the petioles were above the surface of the water. The sample so treated was then immersed for 2 hours in water at room temperature and gently agitated to dislodge air bubbles and to insure wetting. When removed from the water the leaves were shaken gently to dislodge adhering drops and then dried between blotters for a few minutes. They were then spread out in the laboratory for 5 to 10 minutes until the surfaces were apparently dry, and again weighed. In many cases when the weight after immersion was still considerably less than the fresh weight, the process was repeated for another 2 hour period, and in a few cases longer periods were used.

The leaves for this study were obtained from the collection of fruit plants at the Minnesota Fruit Breeding Farm. Nearly all were obtained from plants growing in the field. Those from the less hardy sorts were taken from trees or shrubs growing in tubs but maintained under outdoor conditions during the growing season. In all cases normal uninjured leaves of medium age were used. Those that were obviously too young or too mature were excluded from the samples.

Results

The data obtained are presented in the accompanying table. No attempt was made to measure the varying rates of absorption nor to note to what extent the proportionate loss by wilting affected the

ability of the foliage to recover turgidity. It is apparent from the data, however, that all the genera and species studied were able to regain some or all of the weight lost in wilting. In many cases immersion for more than 2 hours was necessary in order to regain approximately the fresh weight. The genus Rubus as a whole apparently was able rapidly to absorb sufficient water to restore turgidity. In nearly all the samples of Rubus, including several not listed in the table, the weights were noticeably above the fresh weight after immersion for 2 hours. In a few cases, notably with *Vitis labrusca* variety Concord, *Pyrus communis* variety Bosc, *Prunus avium* variety Bing, *Sambucus canadensis,* and *Ribes sp.* variety Red Lake, the absorption of water was noticeably slower than in the majority of the experiments.

Peculiarities of behavior were noted in several cases. In a sample of *Prunus tomentosa* not shown in the table, the leaves were still limp after immersion for 4 hours. It was observed that the densely matted hairs retained air so that wetting of the leaf surfaces was prevented. A second sample prepared in the usual way but with the leaves gently rubbed under water to remove the air and wet the surfaces readily regained turgidity and the weight lost in wilting. One sample of *Prunus avium* variety Bing gained no weight after 2 hours in water obviously due to failure of the leaf surfaces to wet. It was necessary to keep this sample immersed for 16 hours before turgidity was regained. Several samples of Prunus and Pyrus developed either a spotted or general water-soaked appearance after 4 hours immersion. This condition appeared in some cases before turgidity was regained as in the case of *Prunus persica* variety Marquette, or before the fresh weight was regained as in the case of *Pyrus communis* variety Bosc. Although it was obvious that this water-soaked appearance was due to the accumulation of water in the intercellular spaces it was not determined whether this water entered through the stomates.

From the experiments included in the table as well as many others, it was evident that leaves from both new and fruiting canes of representatives of the genus Rubus readily regained turgidity when immersed for 2 hours, and in most cases weighed more than in the fresh condition. In a preliminary study a single leaf of Rubus (Latham) recovered turgidity each time in four repetitions of wilting and immersing. Similarly the representatives of the genus Fragaria readily regained turgidity and weight although the ever-bearing varieties required immersion for 4 hours.

Additional studies were made with certain raspberry and strawberry varieties to observe their ability to absorb water. Ten leaves from a fruiting cane of the Latham raspberry were wilted until there was a loss of 9.6 per cent of the fresh weight. These leaves were suspended in a glass jar in a saturated atmosphere for 144 hours. During this time the sample declined slightly in weight, probably due to respiration, until 10.5 per cent of the fresh weight was lost. The sample was then immersed in water for 2 hours and regained all but 3.7 per cent of the lost weight. In a similar experiment with leaves of the Minnesota strawberry a loss by wilting of 9.5 per cent of the fresh weight not only was not regained in a saturated atmosphere but a further loss of 1.8 per cent was noted after 72 hours.

TABLE I—ABILITY OF WILTED FOLIAGE TO REGAIN WEIGHT AND TURGIDITY UNDER LABORATORY CONDITIONS

Species	Variety	Per cent Loss in Wilting	2 Hours in Water			4 Hours in Water		
			Per cent Regained	Per cent Fresh Weight	Turgidity Regained	Per cent Regained	Per cent Fresh Weight	Turgidity Regained
Amelanchier canadensis	Seedling	14.8	6.0	91.2	?	9.5	94.7	?
Carya ovata	Seedling	7.3	5.6	98.3	?	8.2	100.9	?
Carya cordiformis	Seedling	3.4	3.1	99.7	Yes	—	—	–
Corylus americana	Hardin	5.9	6.5	100.6	Yes	—	—	–
Corylus americana	Winkler	5.6	5.8	100.2	Yes	—	—	–
Corylus avellana	Daviana	7.1	5.2	98.1	Partly	8.4	101.3	Yes
Cydonia oblonga	Meech	8.1	4.0	95.9	No	6.2	98.1	Partly
Fragaria virginiana x *chiloensis*	Champion	7.9	7.7	99.8	Partly	9.1	101.2	Yes
Fragaria virginiana x *chiloensis*	Mastodon	6.9	4.5	97.6	Partly	7.7	100.8	Yes
Fragaria virginiana x *chiloensis*	Progressive	8.6	7.7	99.1	Yes	9.2	100.6	Yes
Fragaria virginiana x *chiloensis*	Wayzata	6.0	2.8	96.8	Partly	5.1	99.1	Yes
Fragaria virginiana x *chiloensis*	Beaver	7.5	7.6	100.1	Yes	—	—	—
Fragaria virginiana x *chiloensis*	Gibson	12.5	12.3	99.8	Yes	—	—	—
Fragaria virginiana x *chiloensis*	Minnesota	8.7	9.7	101.0	Yes	—	—	—
Fragaria virginiana x *chiloensis*	Premier	9.2	9.0	99.8	Yes	—	—	—
Juglans cinerea	Seedling	6.0	5.7	99.7	Partly	—	—	—
Juglans nigra	Thomas	8.4	2.7	94.3	No	7.4	99.0	Yes
Malus baccata	Beauty	14.7	11.6	96.9	Partly	—	—	—
Malus domestica	McIntosh	10.1	3.8	93.7	No	—	—	—
Malus domestica	Wealthy	11.1	7.7	96.6	Partly	—	—	—
Malus ioensis	Tipi	11.2	6.7	95.5	Partly	—	—	—
Morus alba	Seedling	5.1	4.2	99.1	Yes	—	—	—
Prunus americana	Terry	13.4	9.2	95.8	Partly	11.5	98.1	Yes
Prunus americana	Wyant	10.0	6.6	96.6	Partly	9.9	99.9	Yes
Prunus americana x *salicina*	Tonka	9.0	3.9	94.9	Partly	6.4	97.4	Partly
Prunus americana x *salicina*	Underwood	9.7	4.4	94.7	Partly	8.9	99.2	Yes
Prunus armeniaca	Harris	4.0	4.8	100.8	Yes	—	—	—
Prunus armeniaca	Van Ness	6.6	3.8	97.2	No	9.2	102.6	Yes
Prunus avium	Bing	9.5	2.6	93.1	No	4.1	94.6	Partly

Prunus cerasus	Montmorency	11.8	5.8	94.0	?	10.6	98.8	?*
Prunus domestica	Russian Green Gage	9.4	8.0	98.6	Partly	11.6	102.2	Yes*
Prunus glandulosa	Seedling	8.2	1.8	93.6	Partly	9.2	101.0	Yes
Prunus nigra	Olson	10.1	4.6	94.5	Partly	10.2	100.1	Yes
Prunus nigra	Pembina	4.5	3.9	99.4	Yes	—	—	—
Prunus persica	Marquette	14.7	13.2	98.5	No	20.1	105.5	Partly
Prunus persica	Rochester	8.4	3.6	95.2	No	11.2	102.8	Yes*
Prunus salicina	Burbank	8.4	4.3	95.9	No	8.2	99.8	Yes
Prunus tomentosa	Seedling	8.5	9.1	100.6	Yes	—	—	—
Prunus virginiana	Seedling	5.5	1.6	96.1	No	4.3	98.8	Partly
Pyrus communis	Bosc	10.1	.5	90.4	No	7.3	97.2	Partly*
Pyrus communis	Patten No. 3	9.2	6.8	97.6	Partly	10.3	101.1	Yes*
Pyrus ussuriensis	Harbin Seedling	9.5	10.0	100.5	Yes	—	—	—
Ribes sp.	Red Lake	8.0	1.8	93.8	No	4.3	96.3	Partly
Rubus occidentalis	Cumberland new canes	10.5	13.0	102.5	Yes	—	—	—
Rubus occidentalis	Cumberland fruiting canes	14.1	17.6	103.5	Yes	—	—	—
Rubus strigosus	Chief new canes	10.1	10.3	100.2	Yes	—	—	—
Rubus strigosus	Chief fruiting canes	9.4	12.1	102.7	Yes	—	—	—
Rubus strigosus (?)	Latham new canes	9.6	10.4	100.8	Yes	—	—	—
Rubus strigosus	Latham fruiting canes	11.6	20.0	108.4	Yes	—	—	—
Rubus sp. (?)	Blackberry new canes	10.3	9.0	98.7	Yes	—	—	—
Sambucus canadensis	Seedling	4.0	.7	96.7	No	—	—	—
Viburnum opulus	Seedling	6.0	2.3	96.3	?	5.3	99.3	?
Vitis labrusca	Concord	5.0	.9	95.9	No	—	—	—
Vitis vulpina	Beta	8.7	2.9	94.2	No	—	—	—

*Leaves more or less water-soaked.

As the above experiments indicated failure to absorb water from a saturated atmosphere a sample of leaves from fruiting canes of the Latham raspberry were wilted until 8.9 per cent of the fresh weight was lost. The sample was then dipped in water for an instant to simulate a light shower, and the sample then suspended in a saturated atmosphere. In 100 hours there was a gain of 7.2 per cent in weight and the leaves were nearly turgid. A similar sample from the Chief raspberry wilted until 15.0 per cent of the fresh weight was lost, then dipped and suspended in a saturated atmosphere regained in 100 hours all but 0.4 per cent of the fresh weight. At that time the leaves were turgid and appeared normal in condition. In both of these experiments after 24 hours drops of water were still present on the under surfaces of the leaves but on the upper surfaces all had been absorbed. This difference appeared to be due to the fact that the drops on the upper sides were in contact with the surface whereas the dense mat of hairs interfered with contact on the under surfaces. After 100 hours all the drops had been absorbed.

In another experiment a sample of leaves from new canes of the Latham raspberry was wilted to 84.2 per cent of the fresh weight and then floated on the upper surfaces and the vessel covered to obtain an approximately saturated atmosphere above the water. The sample was dried and weighed after 2, 4, and 6 hours and the weights in per cent of the fresh weight were 86.6, 92.1, and 93.1, respectively. It was apparent that water was absorbed by the upper surfaces but the rate of absorption was not as rapid as with similar material immersed in water.

In a final experiment fruiting laterals of the Latham variety were cut in the field and taken to the laboratory with the stems in water. The cut end of the stems were sealed with paraffin and the sample wilted for 70 minutes. At that time loss in weight ranged from 8.1 to 13.1 per cent with the weighted average loss 9.89 per cent of the fresh weight. The laterals were then supported on a rack in the laboratory and all surfaces wet for 5 minutes with a fine spray to simulate a light shower. After an interval of 10 minutes the spraying was repeated. This treatment was repeated until 5 sprays had been applied after which the laterals were shaken gently and allowed to dry for 1½ hours. As a little water was retained between each berry and its calyx after the leaves were apparently dry, it was necessary to slightly over-dry the leaves to reduce such surface water to a minimum. When weighed, the individual laterals ranged from 95.4 to 102.6 per cent of the fresh weight with the weighted average 99.8 per cent. The leaves were turgid and apparently in normal condition, indicating that these fruiting laterals were able to recover from severe wilting by the absorption of water principally through the leaves.

Conclusions

The leaves of all the species and varieties studied apparently were able to absorb water under laboratory conditions except that certain representatives of Rubus and Fragaria were unable to regain weight in a saturated atmosphere. In all cases both the wilting and exposure to water were extreme treatments but indicate the general ability of

the leaves of these species to recover turgidity where they come in contact with water in such a way that the surfaces are wetted. The results obtained are in agreement with those of other workers and indicate the probability that the leaves of fruit plants are able to absorb water when wet by rain or by overhead irrigation and thus contribute in a minor way to the water intake of the plant. Differences in the amount or rate of absorption probably are due to the factors noted by Kessler and also to other factors such as the internal structure of the leaf, the ease of water conduction, and the kind, amount and degree of hydration of the various hydrophyllic colloids present within the cells.

The writer is indebted to R. H. Landon for assistance in reviewing the literature related to these studies.

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Size of Peaches as Affected by Soil Moisture

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THE results herein reported were obtained in 1933 and 1934 in a Phillips peach orchard planted in 1923 on a Yolo loam at Davis, California. Differential irrigation was started in 1931, the trees up to that time having been given uniform treatment.

Each plot consisted of eight trees surrounded on all sides by guard trees that were given the same irrigation treatment as the irrigated ones. The distribution of the four plots in each treatment followed, essentially, the Latin square arrangement. The field capacity of the top 3 feet of soil was about 22 per cent, and for the second 3 feet, about 18 per cent. The permanent wilting percentages were about 11 per cent, and 9 per cent, respectively. Four irrigation treatments were used, hereafter designated by the Letters A, B, C, and D. In treatment A the soil moisture was maintained above the permanent wilting percentage throughout the year. This treatment was irrigated when the soil moisture in the top 3 feet was reduced to about 13 or 14 per cent. In other words, the soil moisture was replenished considerably before the available supply was exhausted.

In treatment B the trees were allowed to extract the soil moisture in the top 6 feet to approximately the permanent wilting percentage before the supply was replenished. During both 1933 and 1934, however, the readily available moisture was exhausted in this treatment for a period of about ten days before harvest. Irrigation of this treatment was delayed because of the inconvenience of picking, shortly after an irrigation. Treatment C was irrigated in the same manner as treatment A in the early part of the season, but it was not irrigated after July 1. Treatment D was not irrigated during the growing season.

When plotted against time, the fruit showed three distinct periods of growth as has been pointed out by other workers. In 1933, for example, the first period of rapid growth ended during the first week in June; the second period of slow growth lasted from early in June until fairly late in July, when the fruit entered the final period of rapid growth. Measurements of hundreds of fruits during a period of many years show that the increases in size follow the trend given above as long as readily available moisture is present in the soil. As pointed out in a previous publication (1) a marked decrease in the amount of growth is noticeable when the soil moisture has been reduced to about the permanent wilting percentage. For example, in 1933 the fruit in treatment D began to grow slower than that in the other treatments about the middle of July when the readily available soil moisture was exhausted in the top 6 feet. Similarly, the fruit in treatment C began to slow down in growth about August 7, and the soil moisture record showed that the permanent wilting percentage was reached about August 10 which was the nearest sampling date. Likewise, the readily available soil moisture in the top 6 feet in treatment B was exhausted the first week in September and the fruit grew

more slowly after that time. Because of the unusually late harvest in 1933, we were able to obtain evidence on the effect of the lack of available soil moisture and the growth of the fruit in three of the four treatments. Essentially similar results were obtained in 1934. No data are available on the possible effect of lack of readily available moisture during the early part of the fruit growing period, because under normal rainfall conditions at Davis, it is not possible to have the soil moisture reduced to about the permanent wilting percentage until late in June or early in July.

One of the rather surprising results that we have obtained during a period of years is that relating to the total yield of fruit. While we have obtained large differences in total yields since 1930 between treatments A and D, the total yields from B and C have sometimes been about as large as, and, in a few cases, larger than those from A. These results were rather surprising in view of the relatively severe conditions to which the trees in treatments B and C were subjected. The cultural operations such as pruning, spraying, and thinning were uniform on all treatments. The yields given in Table I show that all treatments produced nearly equal crops in 1929 and 1930 before differential irrigation was started, and that the crops from treatment D were smaller than the others since that time. However, when the amount of fruit that could be delivered to the cannery (minimum size 2⅜ inches in diameter) is considered, the effect of the lack of readily available soil moisture during the growing season is apparent. The amounts of marketable fruits produced are given in Table II.

TABLE I—AVERAGE YIELDS OF PEACHES OF ALL SIZES

Treatment	Yield (Tons per Acre)					
	1929	1930	1931	1932	1933	1934
A	6.2	7.8	9.2	12.2	12.6	11.9
B	5.9	7.6	8.3	12.5	12.8	11.1
C	5.7	7.6	8.0	11.6	8.2	8.4
D	6.4	7.9	5.6	6.5	1.5	2.0

TABLE II—AVERAGE YIELDS OF PEACHES, 2⅜ INCHES OR LARGER IN DIAMETER

Treatment	1933 Yield		1934 Yield	
	Tons	Per cent of Total Crop	Tons	Per cent of Total Crop
A	9.0	71.4	9.0	75.6
B	7.4	57.8	4.9	44.1
C	1.2	14.6	3.5	41.7
D	0.1	0.07	0.2	0.1

Treatment A which was kept supplied with available water throughout the growing season produced more than 70 per cent of marketable fruit. The other treatments which were without available soil moisture for periods ranging from about 10 days to several weeks before

harvest produced a much smaller percentage of marketable fruit than treatment A. It is evident from these results that when certain sizes of peaches are required, it is important that the trees be kept supplied with readily available water throughout the season. Furthermore, the lack of readily available water during the fruit growing period is reflected in the size of the fruit even when only light or moderate crops are produced.

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The Volume Increase in Elberta During the Harvesting Period

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PEACH growers in Illinois, and probably in other states as well, are tempted to start picking while the fruit is in an immature condition, because of price advantage at the time or because of the risk from unfavorable weather when a large acreage is involved. Fruit harvested before the ground color has taken on any appreciable amount of yellow never develops good quality, and, further, when harvested too early the maximum volume of the crop cannot be obtained (3). With this situation in mind, studies have been made to determine the volume increase in the peach during the picking period. Data bearing on this phase of the growth of the fruit are summarized in the different graphs included in this paper. All of the curves are based upon the suture diameter of individually tagged fruits, the volume being calculated as volumes as outlined by McMunn (1).

The 1929 results:—In the Perrine orchard, at Centralia, where the measurements were made in 1929, there was no rainfall from the middle of July until after the picking season. The surface soil was so dry that ammonium sulfate applied about July 20, lay undissolved on the ground under the trees until after harvest. The growth of fruit on selected trees was measured from July 30 until August 29. In order to determine how long, under such adverse conditions, the peaches would continue to increase in volume, none of the fruit was picked until the soft ripe stage. The first fruit was picked in this experiment on August 24 and the remainder on August 29, while the regular orchard picking was started on August 16, when the fruit was hard ripe, and finished on August 25. Curves 4, 5, and 6 in Fig. 1 illustrate that the enlargement rate of the fruit in this orchard was surprisingly rapid under the prevailing conditions.

The 1933 results:—At the University Farm, Olney, fruit enlargement was followed on trees which had received heavy, medium, and light pruning, i. e., thinning out. These three were compared with fruit borne by trees which had received no pruning for 3 years. All of these trees bore a heavy crop in 1933, which was not thinned. The rainfall in this orchard was ample for sizing up the fruit, 5.35 inches falling in July and 1.51 inches in August up to the end of the picking season. Fruit in this orchard was harvested in a more mature stage than in any of the other orchards. Harvesting was started on August 18, which was from 6 to 7 days later than the first picking in the region in 1933. By referring to the enlargement rate of the fruit in the different pruning treatments represented by Curves 7 to 10 inclusive in Fig. 1, it will be seen that a rapid increase in volume took place on each of the trees; the size of the fruit, however, tends to follow the severity of pruning. These curves are based upon detailed measurements of 30 to 40 fruits in each treatment.

The 1934 results:—Data taken in the C. F. Heaton orchard, New Burnside, in 1934 were on trees which had an abundant supply of

available moisture throughout the season. The July rainfall was 2.51 inches. On August 1, 2.87 inches fell; this was followed by light showers on August 2, 3, 6, 9, 11, 12, 13, 14, 16, 17, 19, 20, and 21. In this experiment 1200 fruits were tagged and measured on August 15; subsequent measurements were made on August 17, 20, and 22. The fruit tagged on August 15 was of uniform ground color and closely approximated that of the peaches being picked in the orchard on that date. The ground color at the time corresponded very closely to Ridgway's (2) Yellow Green Plate *VI 31*. Pickings were made on the trees under test on August 15, 17, 20, and 22. It will be noted from Curve 3, Fig. 1, that there was no "sudden increase" in size of the remaining fruit after a part of the crop was removed.

In the M. J. McBride orchard, Villa Ridge, in 1934, measurements were made of 100 fruits on an unthinned tree carrying an excessive crop and of 90 fruits on a thinned tree carrying a light crop. Rainfall records in this orchard were comparable with those at New Burnside, so that a moisture deficiency did not markedly affect size. Harvesting was started on the unthinned tree on August 8 and on the thinned tree on August 10. The fruit in this orchard was picked in a more immature condition than those in the Heaton orchard. Curves 1 and 2 in Fig. 1 show the relative rate of fruit growth on the thinned and unthinned tree.

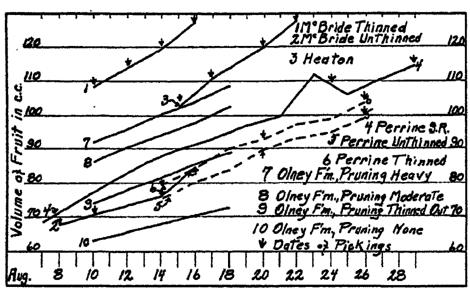

FIG. 1. Showing the increase in volume of fruit during the later part of the final swell, usually during the picking period.

Referring now more specifically to the different graphs of Fig. 1, it will be seen that fruit from each of the different orchards increased rapidly in volume during the harvesting period. In the Heaton orchard (Curve 3) the increase in volume amounted to 7.8 per cent by August 17, 16.5 per cent by August 20, and 24.4 per cent by August 22. If August 17 is considered the first date of picking in the Perrine orchard (Curve 4), there was an increase, in spite of the dry weather, of 4.1 per cent by August 19, 7.4 per cent by August 21, and 20.7 per cent by August 23. The fruit on the thinned tree (Curve 1) in the McBride orchard showed gains of 4.9 per cent on August 12, 10.0 per cent on August 14, and 17.3 per cent on August 16; while on the unthinned tree (Curve 2) the gains were 3.8 per cent on August 10, 10.2 per cent on August 14, and 24.8 per cent on August 16. The percentage increase by volume at the Olney Farm on August 12, 14, 16 and 18 were, respectively: For the non-pruned trees (Curve 10), 4.0, 7.7, 11.7, and 15.2; for the thinning-out type of pruning (Curve 9), 4.7, 9.4, 14.1, and 18.2; for the medium pruning (Curve 8), 4.4, 9.0, 13.7, and 18.5; and for the heavy pruning

(Curve 7), 4.4, 9.0, 13.4, and 18.0. These figures show the increase in volume under all conditions that may be expected with maturity or by delaying picking. This same tendency is also seen in the results of other workers in this field.

Effect of picking upon growth of fruit:—Many growers are of the opinion that after each picking there is a sudden increase in size of the fruit remaining on the tree on account of the reduction in the number of fruits as the season advances. Some go so far as to consider the first picking as a partial substitute for earlier thinning. The growth curves in Fig. 1 show no indication of a sudden increase in volume following the different pickings.

Further evidence that such does not occur was secured in 1929 in the Perrine orchard. On August 14, 226 fruits were removed from one-half of a tree that had been given the regular 5-inch thinning earlier in the season. On this half of the tree, 448 fruits were left, while on the other half there were 709 fruits. Referring to Fig. 1, Curves 5 and 6, it will be seen that the fruit on the two sides of the tree increased in volume at approximately the same rate; although the size level reached by the thinned side of the tree was higher, this was due to the fact that the smaller fruits were thinned off on August 14.

Length of time the peach increases in volume:—In view of the trend of the above results, it will be of interest to note how long the peach continues to enlarge after the soft ripe condition is reached. In this phase of the study three peaches growing on a tubbed Elberta tree in the greenhouse were placed upon separate scales sensitive to 1/100

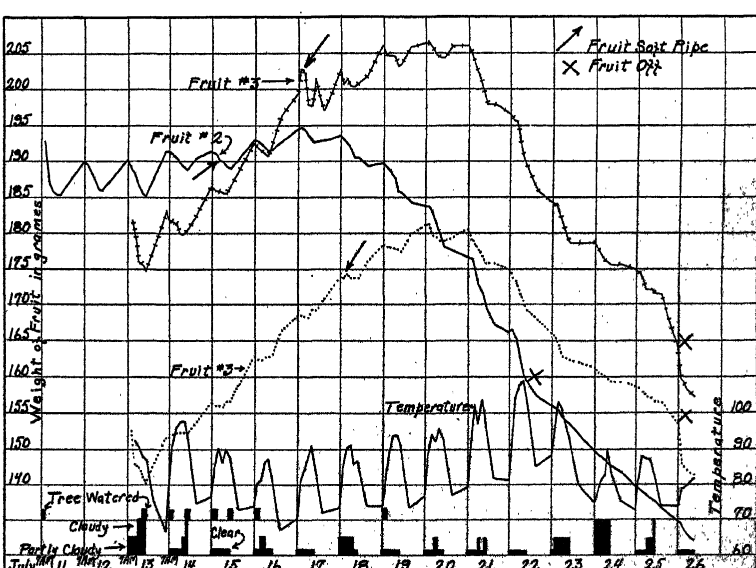

FIG. 2. Showing the growth in grams of peaches on a greenhouse tree from the hard ripe period until they parted from the stem.

of a gram. In order to eliminate limb weight or pressure as far as possible, the three fruits selected were growing on long slender "hangwood" branches 18 to 22 inches in length. These were raised to the horizontal and the peaches placed on the scales with the limb in that position. In order to keep the individual fruits in place on the scales during the time the weights were being taken, a small flat box with a circular hole in it was placed on the weighing pan of the scales. The weights were corrected for box weight and limb pressure after the records were completed. Weight records were made daily at 7, 9, and 11 a.m. and 1, 3, 5, and 9:30 p.m., beginning when the peaches were hard ripe.

The weight records of the three fruits show that enlargement continues for 2 to 3 days after the soft ripe stage is reached but that after that time there is a rapid decline in weight. These fruits remained attached to the shoot longer than under orchard conditions because it was not necessary for the tissues of the stem to support the weight of the fruit. An important factor in the loss of weight may be sought in the partial and gradual cutting off of the conducting tissues during the ripening process. This undoubtedly began at the end of the volume increase. Another feature of interest revealed by the sensitive scales used was the pronounced diurnal fluctuation in weight even though the tree was given an adequate water supply and was placed in a greenhouse where the humidity was high.

These experiments show some interesting trends in the growth of the peach: (1) During that part of the final swell included in the picking season there is, even under the most adverse growing conditions, a rapid increase in the volume of the fruit. This is so pronounced that the volume of the crop is rapidly increased by delaying picking. (2) The different pickings during harvest do not seem to be the equivalent of earlier thinning in increasing the size of the fruit because there does not seem to be a pronounced increase in the growth rate immediately following the removal of a part of the crop. (3) After the soft ripe stage is reached enlargement continues for a few days but under orchard conditions the fruit would probably drop before the maximum size was reached. (4) The diurnal loss in weight indicates that there would be a slight advantage in picking early in the day, especially in dry hot weather. Also, experimental shipments of fruit harvested as much as 7 days after the normal picking date have held up in transit and storage, and were of much better quality than fruits harvested earlier (3).

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A Growth Study of the Cherry Fruit

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PREVIOUS growth studies of the apricot (1), peach (2), and plum (3) fruits suggested a general existence of growth periodicity in stone fruits. This paper offers evidence of its presence in the sweet cherry. Speculations have been made as to the factors underlying this periodic growth in drupaceous fruits. Certain correlated embryo and pericarp relationships have been advanced as possible explanations. The researches of Tukey (4, 5, 6) at Geneva, New York, are especially interesting in this connection and it was to ascertain how generally his conclusions might apply that a somewhat similar study was undertaken at Davis, California.

METHODS, MATERIALS, AND PROCEDURE

Cross-diameter measurements of four varieties, Early Purple Guigne, Napoleon (Royal Ann), Chapman, and Lambert were made weekly in 1933, using a specially designed caliper.[1] The varieties were selected to represent early, mid-season, and late-ripening kinds. These were repeated in 1934 with two additional varieties included, viz., Downer and Lewelling. The 1934 data (Table V) are discussed in detail. The previous season's work had indicated the necessity of early and frequent measurements and the interval between sampling was shortened in 1934 so that the growth was recorded every 2 to 4 days. The abruptness in the change in rates of growth as the fruit passes from one period into the next makes it possible with frequent measuring to establish rather accurately the critical points of inflection in the growth curves and the duration of each period.

Thirty fruits of each variety were tagged early in the season and these same fruits were measured throughout the season. The loss of "original fruits" was low and seldom exceeded 10 per cent. When a loss occurred early in the season, another fruit of approximately the same size was substituted and a record made so that it was possible to follow the growth of individual fruits to maturity.

Samples of fruits from limbs adjacent to those which bore the tagged fruits were picked and placed in a formalin alcohol solution. Measurements of the endocarp were made on these observed fruits, using a dissecting microscope and a movable calibrated stage. When the pits were too hard to cut these measurements were made by removing the flesh and using the calipers.

PRESENTATION OF DATA

Growth studies of deciduous tree fruits are generally based on the average diameter of a number of fruits measured at stated intervals. Greater accuracy is attained when the averages are based on measurements of the same fruits throughout the season. But before averages and their variability constants are calculated, it is generally desirable to examine growth curves of the individual fruits, especially when one is interested in establishing periodicity and the duration of each

[1]Modified design, Model 49, Federal Products Corporation, Providence, R. I.

growth phase. A lack of synchronism in the growth of individual fruits might give rise to errors if only averages are used indiscriminately. Growth curves of individual fruits may reveal isochronous periods of depressed growth which may not be synchronous and the growth behavior based on the average may, therefore, be misleading.

The growth increments of individual Early Purple Guigne cherries are presented in Table I. It is evident from this table: (a) that all the fruits exhibit periodic growth, namely, an early rapid growth, then an interim of lesser growth, which is followed by another period of very rapid increase; (b) that all the fruits do not enter and emerge from the period of depressed growth simultaneously and; (c) that the duration or extent of the depressed period is not the same for all the fruits of this variety. Reference to Table I establishes the fact that fruits numbered 7, 16, and 22 entered the depressed period relatively late while fruits numbered 10, 19, 23, 25, and 27 emerged from the same period somewhat early. The duration of the period of retarded growth varies from 8 days (fruit No. 23) to 16 days (fruit No. 13).

TABLE I—CROSS DIAMETER GROWTH INCREMENTS (MM) OF INDIVIDUAL FRUITS OF THE EARLY PURPLE GUIGNE CHERRY, 1934

The Table Presents Evidence of Variations in the Extent of the Depressed Period of Growth. The Growth Increments in the Depressed Period are italicized.

Fruit Number	Date											
	3-24 to 3-28	3-28 to 3-30	3-30 to 4-3	4-3 to 4-5	4-5 to 4-7	4-7 to 4-9	4-9 to 4-11	4-11 to 4-13	4-13 to 4-16	4-16 to 4-19	4-19 to 4-23	4-23 to 4-25
1	—	—	—	*.5*	*.5*	*.4*	*.4*	*.6*	2.0	2.4	2.7	.4
2	—	—	—	*.6*	*.4*	*.5*	*.8*	1.6	2.4	2.8	1.6	0
3	3.1	*.8*	*.4*	*.5*	*.2*	*.5*	*.8*	1.3	2.6	2.2	1.7	.7
4	2.7	*.6*	*.5*	*.3*	*.5*	*.6*	1.1	2.0	2.7	1.4	1.2	.6
5	2.9	*.6*	*.7*	*.5*	*.4*	*.8*	*.9*	2.0	3.1	1.7	1.4	.5
6	3.0	*.6*	*.6*	*.5*	*.5*	*.5*	*.9*	1.6	2.5	2.1	2.1	.7
7	1.9	1.2	1.9	*.6*	*.3*	*.3*	*.7*	*.7*	2.0	2.3	2.6	.6
8	2.6	*.6*	*.6*	*.3*	*.4*	*.7*	*.9*	1.9	2.5	1.4	1.8	.8
9	3.1	*.8*	*.5*	*.2*	*.6*	*.7*	*.6*	1.7	2.8	1.9	1.7	1.0
10	2.1	*.4*	*.2*	*.5*	*.5*	1.1	1.3	1.9	1.9	1.5	1.4	.5
11	2.5	*.3*	*.7*	*.7*	*.9*	*.9*	1.4	1.5	1.3	.9	—	—
12	2.8	*.5*	*.6*	*.3*	*.7*	*.6*	1.0	1.9	2.8	1.5	1.5	.6
13	2.9	*.8*	*.6*	*.2*	*.4*	*.4*	*.6*	*.9*	2.6	2.5	2.1	.5
14	1.9	*.4*	*.2*	*.3*	*.3*	*.6*	1.0	1.7	2.6	1.9	1.4	.3
15	2.6	*.5*	*.3*	*.4*	*.4*	*.7*	1.1	1.9	3.0	2.0	1.6	.1
16	2.6	1.0	1.2	*.4*	*.5*	*.3*	*.6*	*.8*	2.5	2.4	2.4	1.1
17	3.0	1.2	—	—	*.4*	*.4*	*.4*	*.4*	1.8	2.3	3.2	.7
18	2.8	*.6*	*.4*	*.3*	*.3*	*.5*	*.5*	1.1	2.6	2.5	2.3	.7
19	2.4	*.5*	*.5*	*.5*	*.4*	1.0	1.2	1.9	2.4	1.6	.9	.5
20	3.0	*.7*	*.6*	*.5*	*.4*	*.9*	1.1	2.1	2.7	1.8	.9	—
21	2.8	1.1	*.9*	*.4*	*.4*	*.5*	*.8*	1.2	2.8	2.4	2.0	.4
22	2.4	1.2	1.2	*.4*	*.4*	*.4*	*.6*	*.6*	2.1	1.9	2.7	.3
23	2.1	*.3*	*.6*	*.7*	1.2	1.6	1.3	1.6	1.9	1.1	.9	.5
24	2.5	1.2	*.9*	*.5*	*.3*	*.5*	*.6*	1.2	2.8	2.2	1.9	.8
25	2.6	*.4*	*.9*	1.3	1.8	1.5	1.6	—	—	—	—	—
26	1.7	*.8*	*.9*	*.6*	*.4*	*.5*	*.6*	1.0	2.6	2.1	—	—
27	2.3	*.2*	*.5*	*.6*	*.8*	1.5	1.6	—	—	—	—	—
28	2.5	*.4*	*.4*	*.3*	*.8*	*.9*	1.3	1.9	2.1	1.4	1.4	.6
29	2.8	*.7*	*.3*	*.3*	*.3*	*.6*	*.9*	1.7	2.7	2.0	1.6	.4
30	2.6	*.5*	*.5*	*.3*	*.4*	*.6*	1.0	1.7	1.6	1.6	1.2	.4

The abruptness in the changes in rates of growth is clearly shown when growth curves of individual fruits are studied. The lack of synchronism just mentioned tends to obscure the "breaks" in the growth curves when the averages of a small number of fruits are used. When the extent of the second period is short, this non-synchronism may mask an existent periodicity. Thus, if fruits Nos. 7 and 25 in Table I are averaged and the values plotted, no periodicity in growth can be detected; whereas these fruits individually exhibit definite periodicity. Furthermore, when the change in rates of growth is not marked as the fruit passes from one period to the next, as in the Climax plum (3), the use of an average may fail to disclose a period of retarded growth which is discernible when fruits are studied individually. Caution is necessary in the use of an average, not only when random samples are taken, but also when the same fruits are measured periodically on the tree.

The composite growth curve derived from the averages of 27 fruits of the Early Purple Guigne indicates a duration of depressed growth of 14 days. The average of the individual data, in which non-synchhronism is not a factor, is 12 days. The standard deviation in the latter case is ± 2.3. From the composite curve (not corrected for non-synchronism), the duration of the depressed period for 30 Downer cherries was 28 days. From the individual data (corrected for non-synchronism) it was found to be 28.6 with a standard deviation $= \pm 3.3$. It may, therefore, be concluded that when 30 cherry fruits are measured and averaged, the matter of non-synchronism is not a serious source of error. However, in the use of small samples this should be given consideration in the analysis of a composite growth curve.

The diameter growth curves of individual fruits of not only cherries but also apricots, peaches, and plums are singularly smooth and the "zigzag" nature of Tukey's data may possibly be attributed to the random method of sampling. If the individual data in Table I are charted, there are no fluctuations similar to those which Tukey (4) has noted for the peach and ascribed to variation in rainfall and temperature.

The composite growth curves of six varieties of the sweet cherry are presented in Fig. 1. All exhibit periodicity. The earlier-blooming varieties—Chapman, Lewelling, Early Purple Guigne, and Downer—enter the depressed period coincidentally. The later-blooming Napoleon and Lambert varieties follow in the sequence of their bloom. The emergence from this period is in the order of their ripening.

Fig. 2 presents the cross-diameter growths of the endocarp in relation to the cross-diameter growth of the entire fruit of the Early Purple Guigne variety. This and similar data (Table II) for the other varieties show the general agreement between the cessation of growth of the endocarp and the inception of the depressed period of growth.

When the diameter growth of the endocarp is subtracted from that of the entire fruit a growth curve for the flesh is obtained, which indicates that the flesh does not cease growth as abruptly as does the endocarp when the fruit passes from stage I to stage II. The slowing down

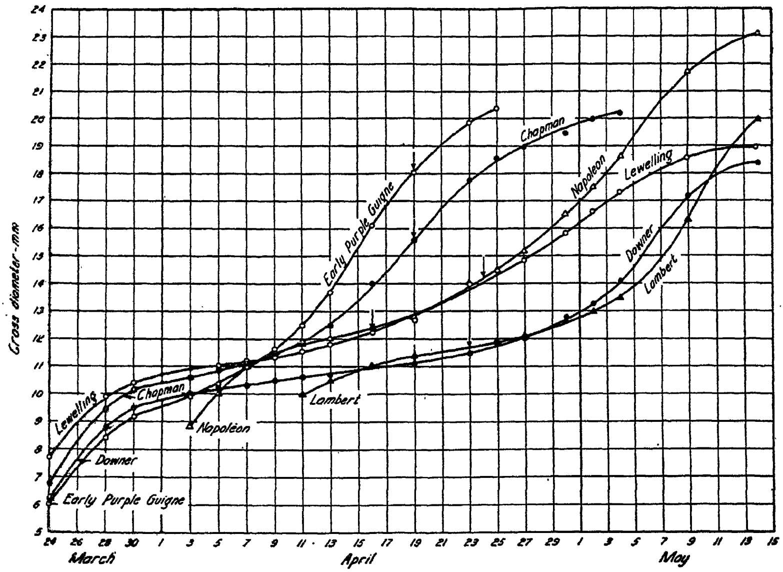

FIG. 1. Composite growth curves of the cherry fruits. The vertical arrow in each curve indicates the time when the embryo for the particular variety has reached its maximum length.

of the growth of the fruit in stage II is, therefore, largely a reflection of the cessation of diameter growth of the endocarp. This cessation of growth of the endocarp appears from 12 to 17 days after full bloom (Table II) and seems independent of the time of ripening (earliness).

TABLE II—COMPARATIVE DEVELOPMENT OF CHERRY FRUITS (IN DAYS)

Variety	First Period	Second Period	Third Period	Total Length of Season	Full Bloom to Max. Size of Endocarp	Initial to Max. Length of Embryo	Full Bloom to Initial Macroscopic Size of Embryo	Full Bloom to Max. Length of Embryo	Max. Embryo Length to Ripening
Early Purple	10	12	15	37	12	14	17	31	6
Chapman	17	13	22	52	17	14	22	36	16
Napoleon	15	14	22	51	15	18	13	31	20
Lambert	14	13	24	51	—	17	13	30	21
Downer	13	28	20	61	13	14	18	32	29
Lewelling	14	22	26	62	14	14	19	30	32

The appearance of the embryo (as determined with the aid of a hand lens) appears also to be independent of the time of maturity of the fruit. The embryo could be detected as early in the late Downer variety as it could in the early-ripening Early Purple Guigne and Chapman varieties and appeared approximately 5 days after the cessation of the rapid growth of stage I. Its growth was complete 14 days later. The macroscopic appearance of the embryo 13 to 22 days after

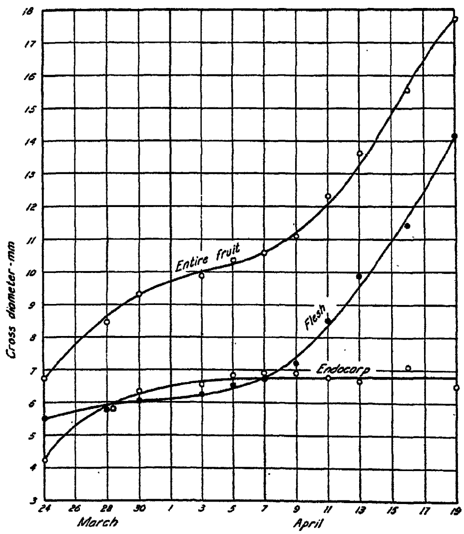

FIG. 2. Growth of the Early Purple Guigne cherry. The agreement between the cessation of growth of the endocarp and the inception of the depressed period of growth is shown.

full bloom and its completion of growth (length) on the thirtieth to the thirty-sixth day in all the varieties irrespective of ripening is striking. Its agreement with similar data presented for peaches by Tukey (4) is to be noted. It appears that there is no correlation between embryo growth as measured by increase in length and the duration of the depressed period of growth and the time of resumption of the rapid growth of the flesh.

The dates of initial and completed growth of the embryo are set forth in Table II. These were determined by examining 10 to 15 dissected seeds from each collection with a hand lens. There appeared to be large variations in the intermediate stages of development of the embryo for any given date. Under these conditions it would be difficult to assign a definite stage of development of the embryo to any one date from the examination of five fruits even with frequent sampling. The smoothness of the growth curves of the embryo as depicted by Tukey (5) suggests a much greater uniformity in development at Geneva, New York, than is attainable from 5 to 10 fruits at Davis, California. Possibly a certain unevenness of bloom which occurs in California after more temperate winters may account for the greater variability in the material studied. This is suggested by unpublished data obtained during the past season on apricots where non-synchronism of growth could be attributed to unevenness of bloom resulting from the warm winter in 1933–34.

The independence of development and growth of the flesh, endocarp, and kernel in drupes, as measured by dry matter increases, has been stressed in earlier publications (1, 2, 3). The time of greatest dimensional growth may not be the time of greatest increase in dry matter. It may be generally stated that the endocarp and embryo complete their dimensional growth before they attain their maximum rate of increase in total solids. The endocarp in the peach is outlined in full size long before its rapid gain in total solids is completed and the rapid increase in the length of the embryo does not account for the rapid increase in the dry weight of the kernel. The lignification of the endocarp, which is largely responsible for its increase in total solids, and the accumulation of fats and oils, which represent a large part of

the increase in total solids in the kernel, are not concurrent with rapid lineal growth of these parts.

This discrepancy is not so marked in the flesh, for its maturation (increase in sugars, etc.,) is more or less synchronous with its increase in size. The data (Table IV) on the comparative growth of the peach kernel as measured (a) by its increase in length, (b) dry weight, (c) green weight, and (d) embryo length, indicate the independence and variance of growth when different measures are used. These data are of interest in connection with the study of embryo growth, embryo abortion, and embryo viability, and their relation to the growth of the other components of the cherry fruit.

The occurrence of embryo abortion as determined by macroscopic examination of immature and ripe fruits was not frequent in the early-ripening varieties. Tukey (5) observed that early-ripening varieties generally possessed embryos which had been suddenly arrested in their development (aborted) and that this occurred during the third period of growth. Table III presents counts, made at harvest time, of normal and aborted seeds in early- and late-ripening varieties at Davis, California. A seed was noted as abortive when the seed coat was incompletely filled. This condition was suggestive of an arrested development of the embryo and a collapse of the remaining nucellar and endosperm tissues.

The conclusions from these data and other unrecorded observations are that early-ripening cherries in California do not characteristically contain aborted embryos. However, during after ripening the seeds from early varieties do shrivel more and lack the plumpness that is more or less characteristic of the late-ripening kinds. This "after-ripening disintegration" should be distinguished from abortion. Such distinction is not possible from Tukey's data. An examination of the condition of the integuments as a criterion of abortion should be made at the time of harvest in order to distinguish between abortion and after-ripening disintegration. The after-ripening disintegration can probably be associated with a low fat content of the seed. In a study of the concomitant growth changes in pericarp and embryo, failure to germinate should not be used as a measure of embryo abortion. Tukey (6) in discussing cherry seed abortion states: "Prior to

TABLE III—THE INCIDENCE OF EMBRYO ABORTION IN SWEET CHERRIES—1933

Variety	Length of Season (Days)	Normal	Aborted	Per cent Aborted
Early Purple Guigne	44	229	13	5.7
Chapman	54	182	17	9.3
Napoleon	68	36	4	11.1
Lambert	74	40	0	0.0
Downer	79	29	0	0.0
Lewelling	86	29	0	0.0

the time of fruit ripening the embryo and endosperm tissue cease developing. The nucellus and integuments subsequently collapse with the result that the seed is characteristically shriveled. Embryos abort

TABLE IV—COMPARATIVE GROWTH OF THE KERNEL AND EMBRYO OF THE ELBERTA PEACH, 1925, EXPRESSED IN PER CENT OF FINAL GROWTH.

Growth at maturity = 100

	5/6	5/13	5/21	5/27	6/1	6/8	6/17	6/24	7/1	7/8	7/15	7/23	7/29	8/5
Dry weight kernel.....	5.9	8.6	12.6	13.5	18.0	16.7	21.4	28.7	42.5	65.0	58.0	77.6	106	100
Green weight kernel.....	38	56	83	91	112	95	98	94	99	99	102	100	97	100
Embryo length.....	0	0	0	9.2	23.5	46.1	75.3	90.6	94.7	95.8	96.3	100.3	99.7	100
Kernel length	75	80	95	100	100	100	100	100	100	100	100	100	100	100
Fat content..	0	0.6	0.8	1.0	2.0	2.0	5.0	8.0	—	55	—	67	75	100

or cease development at various stages from about 1 to 5 mm in length whereas in a normally viable seed of a later-ripening variety the embryos are nearer 6 mm in length. Aborted embryos ultimately disintegrate."

Examination of the Early Purple Guigne seeds preceding or at the time of harvest failed generally to show any early cessation of embryo growth or any collapse of nucellus and integuments. From our examinations it would be hazardous to state arbitrarily that embryos less than 6 mm in length are aborted. Differences in embryo lengths exist within and between varieties and unless some accompanying symptom of incomplete development or disintegration is noted the length cannot serve as a criterion of abortion. An embryo under our conception is aborted when examination reveals premature cessation of growth or evidence of disintegration *while the fruit is on the tree.*

The reciprocal relations of pericarp and embryo growth in early-ripening cherries have been presented by Tukey (5). The fact that early-ripening cherries, as grown at Davis, California, do not have aborted embryos suggests that the early development of the pericarp is not necessarily associated with aborted embryos. A disparity in the growth of the embryo of the Early Purple Guigne when grown at Geneva, New York, and Davis, California, is established.

The lack of viability of seed of early-maturing cherries at Davis is very marked. A study of some of the changes which normally take place in the growth of the peach seed are particularly pertinent in the discussion of the growth, maturity, and viability of cherry seed.

TABLE V—GROWTH OF THE CHERRY FRUIT, 1934
Cross Diameter Measurements (mm)*

Dates of Measurement	Early Purple Guigne	Chapman	Napoleon	Lambert	Downer	Lewelling
Full Bloom	3/19	3/14	3/23	3/30	3/18	3/17
March 24	5.9	6.7	—	—	6.2	7.7
March 28	8.4	9.4	—	—	8.8	9.9
March 30	9.2	10.2	—	—	9.5	10.4
April 3	9.9	10.7	8.8	—	10.0	10.8
April 5	10.4	10.9	10.0	—	10.2	11.0
April 7	10.9	11.1	11.0	—	10.3	11.1
April 9	11.6	11.5	11.5	—	10.5	11.4
April 11	12.5	11.9	11.8	10.0	10.6	11.6
April 13	13.7	12.5	12.0	10.5	10.7	11.8
April 16	16.1	14.0	12.4	11.0	11.0	12.2
April 19	18.0	15.6	12.8	11.4	11.1	12.7
April 23	19.9	17.8	14.1	—	11.5	14.0
April 25	20.4	18.6	14.5	11.9	11.8	14.5
April 27	—	19.0	15.2	12.1	12.0	14.8
April 30	—	19.5	16.5	12.7	12.8	15.8
May 2	—	20.0	17.5	13.0	13.3	16.6
May 4	—	20.2	18.6	13.5	14.1	17.4
May 9	—	—	21.7	16.3	17.2	18.6
May 14	—	—	23.0	20.0	18.4	18.9
May 17	—	—	23.2	20.9	18.6	19.0
May 21	—	—		22.1	—	—

*Averages of 26–30 fruits. Same fruits measured throughout.

From Table IV it may be seen that on May 27 when the peach kernel has attained its maximum length it has acquired only 13.5 per cent of its ultimate dry weight. Likewise, when, on June 17, the embryo has attained 75 per cent of its final length, the dry matter content represents 21 per cent of the dry matter in the seed at harvest time and only five per cent of its final fat content. The maturation of the kernel seems to take place after the embryo has made its major length growth. In the light of these more recent data, the interpretation which Tukey (4) gives Lilleland's data when he states, "This rapid embryo growth accounts for the increase in dry weight of the seed, etc." must be qualified. If we assume from the peach data in Table IV that kernel maturation in the cherry, as measured by increase in fats and total solids, does not take place until after the embryo has made its major length growth, then it may be seen from Table II that in the early cherry varieties this period of maturation is very short and may not permit the early cherry seed to attain full maturity. A kernel low in fat and lacking viability is produced. Fat analyses of the kernels of the Early Purple Guigne, Chapman, and Mazzard seedling have been made and though the data are rather limited, they indicate tentatively that the early-ripening kinds are considerably lower in fat than the later-ripening Mazzard. The whole is suggestive of a nutritionally deficient embryo resulting possibly from the nutritional competition and early maturity of the flesh.

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Notes on Sweet Cherry Doubling[1]

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A HIGH percentage of the sweet cherry flowers in Idaho in 1932 contained two pistils. These doubles made fruit cullage so high that the crop in at least one orchard was not harvested. Flower abnormality was much less serious than in some sections of California where, besides doubling, pistils and petals grew on the end of filaments (1). A few doubles have been noticed since then but damage caused by this condition has been small. The two pistils on one stem were surrounded by one perianth to which was attached the regular number of anthers. At full bloom both pistils usually appeared to be about the same size and to hold equally prominent positions. The cherry flower is differentiated in the fruit bud the season previous to bloom, therefore the condition responsible for forming double (twin) cherries must have existed during the summer of 1931 which, at Lewiston as in California, was unusually hot and dry. Shoot elongation terminated early and the buds near the base of the shoots in the area where flowers are produced the following spring were large by May 27. A morphological description of flower development in the species Prunus including the development of twin ovaries in the Victoria plum has been given by Saunders (2).

The frequency of occurrence of double pistils in 1932 in the Bing, Lambert, and Napoleon varieties in the Mullarky orchard at Lewiston is shown in Table I. The percentage of the flowers containing double ovaries was slightly lower on spurs than on one year shoot growth. In California the doubling was reported to be heaviest near the terminals of the branches (1). In the Mullarky orchard about 46 per cent of the Bing flowers contained double pistils, about 43 per cent of the Lambert, and about 28 per cent of the Napoleon (Table I).

TABLE I—OCCURRENCE OF DOUBLE PISTILS IN SWEET CHERRY FLOWERS

Variety	Flowers on One-Year Wood			Flowers on Spurs		
	Counted Number	Double		Counted Number	Double	
		Number	Per cent		Number	Per cent
Bing	482	238	49.4	292	128	43.8
Lambert	405	181	44.7	217	92	42.4
Napoleon	388	112	28.9	202	57	28.2

Only a small percentage of ovaries develop fruit, consequently these so-called twins produced peculiar conditions. When neither pistil was fertilized the fruit of course did not set and the flower dropped. When only one ovary set it developed into an approximately normal fruit with the other one usually being retained to produce a small growth which became hard, dried, and withered. This was frequently attached to the normal fruit and if pulled off broke the skin, causing the

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fruit to remain a cull. Some few cherries tended to expand the unfertilized twin into a small fleshy growth which if attached made the fruit uneven but otherwise sound. Photographs of some of these conditions are shown by Philp (1). The third condition was where both ovaries produced fruits. Under this condition in the Lambert, the two fruits attached to the same stem often were separate, but in the Bing and Napoleon they usually were united. As the developing twins of the latter varieties enlarged they split at the point of connection farthest from the stem.

The Lambert variety produced the two ovaries more nearly separate than the other varieties studied. These often remained separated until harvest time. If the unfertilized ovary developed a fleshy pericarp it often was small, but if not fleshy the dry remains frequently would slough before harvest. This usually left the normal fruit of the twin marketable and, except for a very slight crease on one side, typical. Shelling of many fruits is a characteristic of this variety every season.

Table II compares the frequency of occurrence of these twins on different exposures of the tree. Doubling occurred most frequently on the south exposure, next on the west, and least on the north.

From one Bing tree 633 fruits formed from flowers with twin pistils were examined. Five hundred and twenty-eight or 83 per cent had only one of the twins developed. Of these the small undeveloped companion in 65 cases was fleshy and in 463 cases shriveled. The remaining 105 were double fruits.

TABLE II—Occurrence of Double Ovaries in Sweet Cherry Fruits at Harvest Time
For Comparison with Table I Twins were Counted as One Fruit Regardless of Type of Development. (100 Cherries from One Limb on Each Side of Each Tree were Counted)

Variety	No. of Trees	Per cent Doubles on Each Exposure				
		South	West	East	North	Av.
Bing	5	59	51	38	28	44
Lambert	4	17	12	13	11	13
Napoleon	2	30	26	21	26	26
Average		35	30	24	22	

A comparison of the flower and fruit counts in the Bing, Lambert, and Napoleon varieties (see Tables I and II) shows the following: About 46 per cent of the flowers of the Bing variety had double pistils and about 44 per cent of the fruits that developed were culls due to having originated from these twins. The Lambert variety with 43 per cent twins showed about 13 per cent of its fruit to be culls due to this cause. The decrease was due mainly to the fact that the unfertilized ovaries in this variety were so readily sloughed. The Napoleon, which was least susceptible to the production of doubles (28 per cent), had 26 per cent of its fruit damaged in this respect. In these three varieties the Napoleon was least susceptible to double pistil formation and

the Lambert outstandingly capable of throwing off the unfertilized ovary while the Bing was susceptible to twinning, but was not capable of sloughing.

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The Effect of Adverse Climate on the Sizing of Cherry Fruits

By R. L. McMunn, *University of Illinois, Urbana, Ill.*

THE data presented in this paper were secured in 1933 while making certain studies with cherry varieties. Starting when ½ to 2/3 of the "shucks" were shed, 50 fruit random samples were taken from each of 12 varieties at 2- to 7-day intervals. The several lots of a variety were taken from the north side of a single vigorous tree. Collections were made not later than 9 a.m. and were taken immediately to the laboratory where the stems were carefully twisted off and volume secured by the displacement method. The data for the 12 varieties are plotted as growth curves and are shown in the two upper sections of Fig. 1.

The weather:—The daily weather readings at Urbana during the period of the collections are shown graphically in Fig. 1; in Table I the averages are shown along with the 1933 records. The actual hours of sunshine are plotted in Fig. 1, while in Table I an average of the clear, partly clear, and cloudy days are given. This change was included because sunshine records have been secured for but 3 years at Urbana.

A survey of the weather data presented in these two summaries shows that the weather during May 1933, was about normal except for rainfall of which there was an excess of 1.95 inches. After the last rain in May the weather changed rapidly and by the end of June the temperature was 7.9 degrees F above normal and the humidity was 18.7 points below normal, both of which are all time departures for the station at Urbana. Although the sunshine records have been taken at Urbana for only 3 years, it is probable that the 395 hours and 22 minutes of sunshine would be in excess of a long-time normal if such a record were available. The excess of clear days over a 14-year period indicates that such was the case. The 1.19 inches of rainfall during June was low, but not as low as in some years. The wind velocity during the period under consideration varied less from the normal than any of the other climatic factors.

On account of the clear, hot dry days in June, the soil became very dry and badly cracked in the top 2- to 3-inch layer. The soil was so hard by June 15 that cultivation was discontinued because the weighted tandom discs "rode on top" of the soil. Even though the upper 2 to 3 inches of soil was depleted of moisture by June 15, apparently there was ample soil moisture below the 3-inch level under the trees as late as June 22. On this date holes were dug under single trees of Paul and Gold to determine the extent of the drying. Under these trees the soil was moist enough below the 3-inch level to hold together when pressed into a ball. After these observations the precipitation of 1.09 inches falling between June 25 to 30 again built up the soil moisture in the upper 3 inches of soil. The ground then remained damp until the next rain of .18 inches which fell on July 9.

Growth of fruit:—A survey of the growth curves (Fig. 1) for 12 varieties reveals that six of them, namely, Early Richmond, Napoleon,

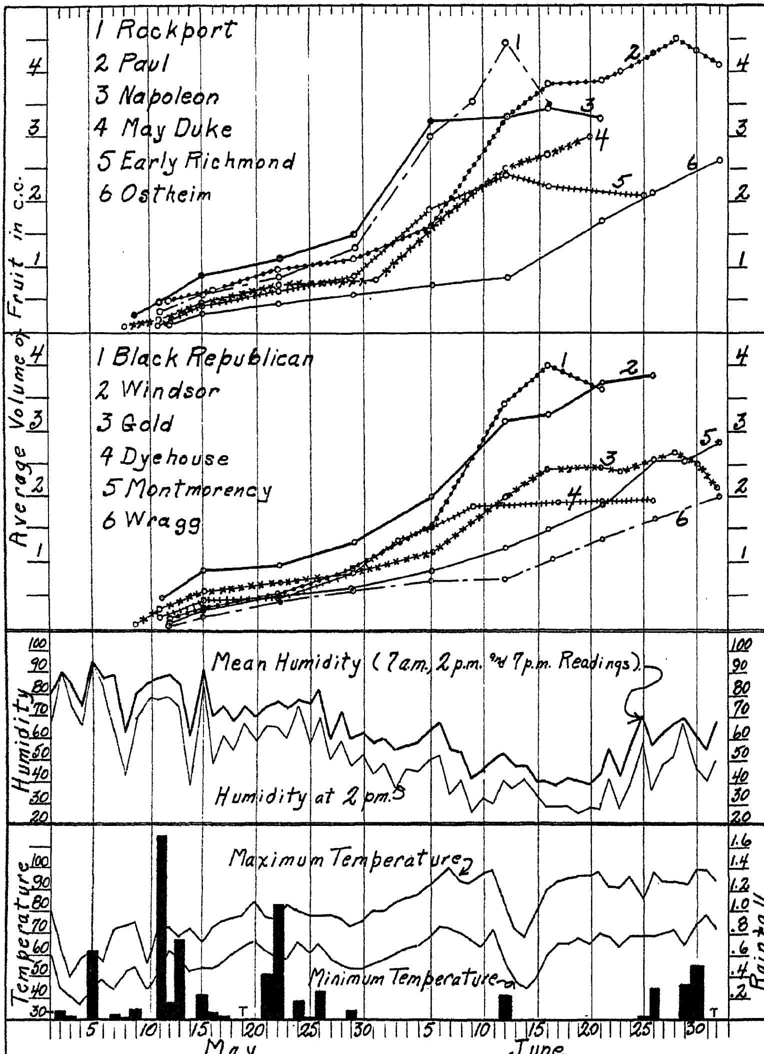

FIG. 1. Graph showing the growth of cherry fruits, the temperature, humidity, and rainfall.

Rockport, Paul, Gold, and Black Republican, decreased in volume and shrivelled as the fruits approached maturity. Both Gold and Paul continued to decrease during and after the rains of June 25 to 30 even though the humidity reached 60; the temperature, however, remained high during this period. Because of the continued shrivelling that took place on each succeeding day, these varieties, except Gold, were har-

TABLE I—SHOWING THE RAINFALL, TEMPERATURE, RELATIVE HUMIDITY, WIND VELOCITY, AND AVERAGE OF CLEAR, PARTLY CLEAR, AND CLOUDY DAYS

Month	Rainfall		Temperature		Relative Humidity*		Wind M.P.H.		Clear†		Partly Clear†		Cloudy†	
	Mean 30 yrs.	1933	Mean 31 yrs.	1933	Mean 45 yrs.	1933	Mean 21 yrs.	1933	Mean 14 yrs.†	1933	Mean 14 yrs.†	1933	Mean 14 yrs.†	1933
May........	3.89	5.84	61.1	63.4	73.8	77.1	8.25	8.17	11.64	10	6.07	4	13.28	17-
June........	3.31	1.19	69.9	77.8	71.8	53.1	7.10	5.88	14.00	23	7.28	3	8.71	4

*Average of 7 a.m., 2 p.m., and 7 p.m. readings.
†An average of the clear, partly clear, and cloudy days are not shown in meteorological reports.

vested a few days earlier than usual, when the fruit is sold in the local markets. Gold was not harvested this year because the fruits were so badly shrivelled and undersize. The last data for this variety shown in the graph was for July 2, which was 5 to 7 days before normal maturity. Unfortunately, readings after July 2 could not be taken, but undoubtedly the completed curve for Gold after that date would have shown a continued sharp decrease in volume. None of the other six varieties decreased in volume, Dyehouse, however, remained stationary over an 11-day period before harvest. Although these varieties did not decrease in volume, they were much smaller than in preceding years.

Factors influencing size:—Several factors that could have influenced fruit size can be eliminated without comment; these are, winter injury to the roots, trunk and branches, root killing or injury because of a high water table, diseases, insects, spray injury, wind damage to fruit and foliage, and excessive yield. The fact that all trees in the orchard made exceptional growth during the very wet month of May would exclude the probability of root injury or inactivity as a factor this season. Also, shoot growth, leaf size and number, and leaf color were better in 1933 than for several years previous.

That deficiency of soil moisture was not the cause of the small size and shrivelling is borne out by the fact that on June 22 the soil was moist at the 3-inch level. Also, the cherry foliage, a vetch cover crop, and a few weeds showed no indications of wilting even during the daytime when the temperature was high and humidity was low. Neither did a heavy irrigation of one Paul and one Gold tree result in an increase in fruit size; the growth of fruit from the two irrigated trees followed exactly the same trend as that on the unirrigated trees of these two varieties.

Several investigators have shown that fruit has marked diurnal changes in volume, even though there is ample soil moisture. Such diurnal fluctuations are brought about by the transpiring leaves creating a deficit of water that cannot be supplied by the root system even though moisture is available. When the leaf deficit can no longer be supplied by the root system, water is withdrawn from the fruit. Under normal growing conditions the water withdrawn from the fruit during the daytime is more than made up during the night; thus the fruit continues to show daily increases in volume. With conditions favorable for a high transpiration rate, such as occurred during most of June, apparently the extensive transpiring leaf surface created such a deficit in the tree and fruit during the 14½ to 15 hours of daylight that this could not be made up during the 9 to 9½ hours of darkness, in six of the varieties. Fruit growth under such conditions would show daily decreases in volume. Apparently the six varieties which did not decrease in size were able to make the adjustment of the daytime deficit during the night.

Another factor which undoubtedly accounts in part for the small size and decrease in volume was the light crop produced by most of the trees. With a light crop and but one or two fruits setting per bud, there were fewer fruits from which water could be withdrawn. Napoleon, Paul, Gold, Rockport, and Black Republican all had very light

crops and in each of these the fruit decreased markedly in volume. May Duke and Montmorency bore about half a crop and in these the fruit increased in size during the unfavorable weather preceding harvest. Although Ostheim, Wragg, and Windsor had but a few fruits left at picking time, they also continued to increase during the season. Possibly the root system of these varieties may have been more efficient than that of the other varieties. It should be noted, however, that all trees of these varieties had been worked on Mahaleb (*Prunus mahaleb*) stock and that since planting, Wragg and Ostheim have pushed out an extensive root system from the scion (*Prunus cerasus*). In the case of Windsor, only a few roots had developed from the scion (*Prunus avium*).

In contrast to the above, Early Richmond was the only tree producing a good crop this year. Even though this variety bore a good crop, the leaf surface was extensive and under the conditions prevailing the fruit decreased in volume. It would appear that when a tree was producing a heavy crop there would be a water deficit set up in both the leaves and fruit rather early in the season. If such were the case, a cessation of growth should occur somewhat earlier than with fruit growing on trees that have only diurnal deficits. Referring to Fig. 1, it will be seen that Early Richmond commenced to decrease in volume earlier than any of the other varieties except Dyehouse, which was carrying three-fourths of a crop and, as a result, showed the same trend as Early Richmond.

A study of the weather records for the past 10 years (period of fruit production in the orchard) indicates that the low humidity was probably more influential in creating the deficit than any of the other factors mentioned. During this 10-year period, the temperature during several harvesting periods has risen to 95 degrees F or above, and this temperature level has been accompanied by clear days with moderate to high winds. Such conditions have often prevailed from shortly before the first picking until after harvest. The fruit during those years has always "sized up," even including 1925, when there was a deficiency of 7.89 inches of precipitation for April, May, and June, and 1932 with a deficiency of 4.96 inches for these 3 months. Since a very low humidity so outstanding during the season of 1933 did not accompany the high temperature and clear days previous to harvest of the past ten seasons, it seems probable that humidity was more influential than the other factors in the failure of the fruit to size up. Chandler (1) cites a similar observation in Missouri during a drought year. On peach trees carrying a good crop with no defoliation, the fruits did not increase to marketable size, with many shrivelling on the trees. In an adjoining orchard, carrying a good crop but with the foliage limited through defoliation the fruits grew to marketable size.

With more detailed studies of the weather that prevails during the season and especially during the "final swell" it may be found that temperature, humidity, and clear days play a far more important part in sizing of the crop than has hitherto been thought.

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Growing Trees from "Non-viable" Peach Seeds[1]

By O. W. Davidson, *Experiment Station, New Brunswick, N. J.*

WORK on the germination of seeds of early maturing varieties of peaches by the use of artificial cultures was started in 1933. The first year's results of this work, discussed in an earlier paper (1), showed need of effective provision against contamination when the cultures are started. They showed, moreover, a need for further study of methods for growing the delicate seedlings after removal from the sterile cultures. This phase of the work was studied during the past season with such results that we feel prepared now to undertake peach breeding with early ripening seed parents.

Improved Methods

Through a refinement of the methods used previously, it has been possible practically to eliminate contamination from the cultures. This was accomplished by autoclaving all containers and media and by using a sterile chamber within which the peach seeds are transferred to the containers.

A transfer chamber was constructed equipped with an atomizer which produced a moisture vapor that carried down suspended spores from the air within it. In over 700 cultures started with the aid of this chamber during the past season contamination developed in only three.

The method used for sterilizing the seeds was adapted from the work of Hopkins, Wilson, and Fred (5). All seed coats were removed, and the embryos were sterilized by immersion in vacuo in 1: 1000 mercuric chloride for 2 or 3 minutes. Following this, they were sterilized in Dakin's neutral sodium hypochlorite solution in vacuo for 5 minutes. The embryos finally were washed in vacuo three times with sterile water.

The results with the first series of cultures treated in this manner showed that mercuric chloride used in vacuo very quickly penetrated peach embryos and markedly reduced germination. Later work proved that immersion in Dakin's solution in vacuo for 5 minutes was an effective means of sterilizing the embryos and was absolutely harmless to them when followed by three washings with sterile water. By the use of vacuum, uniform and effective sterilization was accomplished.

Four-quart cookie jars were used as containers. Thin-walled jars of this type can be sterilized repeatedly. They hold 10 to 12, 1½-inch clay pots in which the peach embryos are placed. These jars provide adequate air space and allow sufficient light to reach the embryos and young seedlings.

One-pint, screw top Mason jars and 2-ounce, screw top bottles also were used. The Mason jars were convenient to use. Moreover, for some reason which is not clear to the author, embryos cultured in them showed a slightly higher percentage of germination than those cultured in the cookie jars.

[1]Journal Series paper of the N. J. Agricultural Experiment Station, Department of Horticulture.

Varieties Used

Seed of three varieties namely, Golden Jubilee, Cumberland, and N. J. No. 71 were used in the 1934 experiments. The first, although not completely "non-viable," produced less than 50 per cent viable seed. The viability of the last was not determined. Nevertheless, judging from its season of ripening, it would be expected to produce about the same or slightly greater viability than Golden Jubilee. Cumberland seeds, on the other hand, were not viable this year unless cultured artificially. This condition may not occur every year since it has been observed repeatedly that the viability of some varieties of peaches vary considerably from year to year. In fact, some varieties that normally possess a high degree of viability may be non-viable in certain seasons. Davis (2) has observed the same peculiarity with Ambrosia seed.

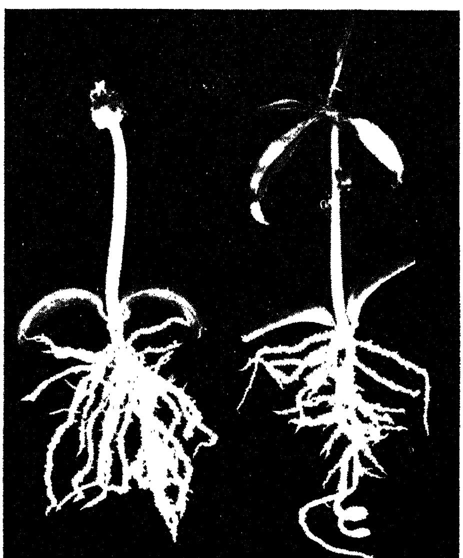

Fig. 1. Seedlings of N. J. No. 71 and Golden Jubilee photographed at the time they were removed from sterile cultures.

Fig. 1 shows seedlings of N. J. No. 71 and Golden Jubilee photographed at the time they were transplanted from sterile culture to the greenhouse. Almost all of the N. J. No. 71 seedlings produced very little top growth. The leaves were small and curled; many of them were white and were not more than ¼ inch in length. The root systems formed by these seedlings were the largest of any of the three varieties. Many of them possessed 8 to 10 roots varying from 2 to 4 inches in length. Seedlings of Golden Jubilee produced much better top growth than those of N. J. No. 71. Some of them showed no abnormality in growth until they attained a height of 3 to 4 inches. Plants from this variety usually produced a smaller root system than plants from N. J. No. 71. Cumberland seedlings resembled those from Golden Jubilee, except that they produced a larger root system than the latter.

After-Ripening Necessary for Normal Growth

It has been shown (1, 4) that peach seedlings produced from non-after-ripened seed grow abnormally. This is illustrated by the plants in Fig. 2. These plants had ceased growth when they were only 2 to 3 inches high, 5 weeks after germination. Plants grown from fully after-

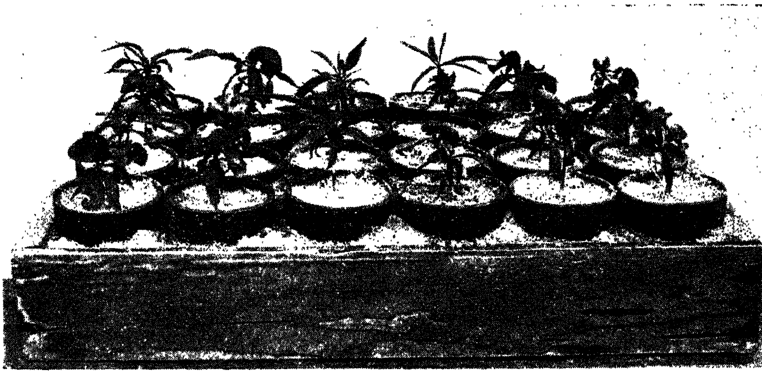

FIG. 2. A group of Golden Jubilee seedlings germinated without an after-ripening treatment. These plants have stopped top growth.

ripened seed usually attain a height of at least 10 to 12 inches in that time. Exposure to temperatures below 45 degrees F for 5 weeks will enable the plants to complete their dormancy and stimulates normal growth later when they are returned to a favorable growing temperature. Without such a cold treatment, or if the treatment given is too short, the tops may remain dormant for 6 months or more.

ABNORMAL TIP DEVELOPMENT

Nearly half of the plants germinated in artificial culture renew growth not from the terminal bud, but from a lateral bud near the tip or, in many cases, from below the collar. It has been observed that most of the plants which exhibit extremely abnormal leaf growth, as shown by the N. J. No. 71 seedling in Fig. 1, usually form no terminal bud. This is illustrated by the stem tips shown in Fig. 3. The tip of such a plant after the leaves have been shed consists merely of a series of abcission scars left from the numerous small, curled, and often white leaves, and shows no evidence of an apical moristem. This condition has not been observed to date in the seedlings grown from incompletely after-ripened seeds of normally viable varieties.

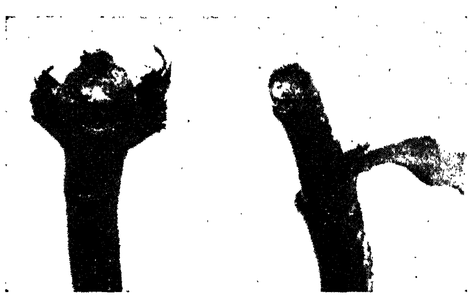

FIG. 3. Abnormal stem tips from embryos germinated without an after-ripening treatment. No terminal buds have been formed.

It is of interest to note that during the germination of these artificially cultured non-after-ripened embryos, the epicotyl developed before, or at the same time as, the hypocotyl. When the seeds were artificially cultured and allowed to remain at room temperature for

8 to 10 days, and then after-ripened for 6 weeks at about 5 degrees C, the hypocotyl developed before the epicotyl. The latter condition likewise prevailed when completely after-ripened seeds of the late season varieties were germinated.

Root growth seemed not to be affected greatly by the lack of after-ripening. New roots continued to form even after the leaves had dropped.

Growing the Plants After Germination

Several methods of handling the young seedlings after germination have been tried. In one, the plants were transplanted into sand in 2½-inch clay pots and given a complete nutrient solution (1) until they stopped growth. After the plants stopped apparent leaf and stem growth, they were given a nutrient solution free of nitrogen. By such treatment the plants were hardened satisfactorily with no injury to the roots. In this respect sand culture offers a distinct advantage over soil culture in that it permits a greater control of plant growth. At this stage the plants were held at room temperature or at a lowered temperature or given a gas treatment (3) to break their dormancy. This method of handling has the disadvantage of requiring growth of the plants in a greenhouse during the hot weather that prevails in New Jersey during August and September. The loss among these plants during the first week in the greenhouse is quite appreciable.

In the second method, holding at temperatures ranging from 3 to 7 degrees C in the presence of an electric light was tried after the plants had been removed from the sterile cultures, but before they were hardened. These treatments, however were not very satisfactory since they resulted in the loss of a large proportion of the plants. The marked changes that occurred in the humidity of the cold storage were particularly unfavorable to the plants. They were attacked by mildew when the humidity was high and they wilted when it was low. The low temperatures alone did not appear to be harmful, as will be shown later.

In a third method, the embryos were allowed to germinate at room temperature and then placed in cold storage at 3 to 7 degrees C for 5 weeks. These plants were not injured to any apparent extent. However, the duration of the cold treatment probably was not long enough, since only about half of these plants grew normally. Of the remaining plants, some continued to produce abnormal leaves while the rest stayed dormant.

By a fourth method, the embryos in sterile cultures were kept at room temperature for 10 days and then placed in cold storage for 6 weeks at 3 to 7 degrees C. Upon being returned to room temperature the embryos germinated quickly. Most of the seedlings in this treatment grew normally. A few of them, however, grew abnormally at first but later made a normal type of growth. These results indicate that the cultures should have remained in cold storage for 2 or 3 weeks longer. They show, also, that this method offers considerable promise as a means of handling large numbers of seedlings. Moreover, by this method it is unnecessary to transplant the delicate seedlings to a greenhouse during the hot weather of August and September.

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Artificial Culture Methods for Isolated Embryos of Deciduous Fruits[1]

By H. B. TUKEY, *Experiment Station, Geneva, N. Y.*

INTRODUCTION

SUCCESSFUL culture methods for abortive embryos of deciduous fruits have been reported by Tukey (5) and have been subsequently used by Davidson (1) with the peach, and by others. The application to problems of plant breeding is obvious, being of peculiar importance in the breeding of stone fruits, in which varieties of peach, cherry, and plum which ripen the fruit early may have a low proportion of, or even no, viable seed. The Abundance cherry, for example, which ripens at Geneva, New York, in early August has nearly 100 per cent normally developed seed, while the Black Tartarian cherry which ripens in early July has only 70 to 85 per cent normally developed seed, and the Early Purple Guigne which ripens in early June has never been known to produce any but abortive seed at Geneva, New York. The same situation applies to peaches and to plums. It can be seen, therefore, that evolution in nature in the direction of early ripening fruit characters is blocked on the female side. Were it not for the horticultural practices of budding and grafting, many of our finest sorts would be lost to cultivation. A method of artificial culture, therefore, which will make development possible in the direction of still earlier ripening fruit characters is of direct practical application to the breeding of stone fruits.

Moreover, quite aside from breeding for early ripening fruit characters is the perpetuation of anomalous forms which might otherwise be lost (7). Horticultural varieties are largely monstrosities, that is, they are abnormalities which have varied in the direction of usefulness to man so that they have been propagated and retained by budding and grafting methods. Artificial culture methods as applied to breeding work make it possible to bring to maturity anomalous individuals which might otherwise fail to develop into mature plants, and subsequently to perpetuate them by horticultural methods of vegetative propagation.

Since the work with cherries in 1932, studies of a more fundamental nature have been made in the culturing of embryos of apple, pear, cherry, plum, and peach during 1932, 1933, and 1934, using different varieties, media, and temperatures. Certain more or less practical suggestions have arisen in the course of this work which may be of immediate value to those interested in methods of artificial culture[2]. Accordingly, they are published for what they may be worth even though subsequent findings may alter them.

MATERIALS

The following varieties have been used during the seasons indicated, representing different seasons of fruit ripening, and different fruit and tree characters. In all, over 12,000 embryos have been cul-

[1]Journal article No. 70 of the N. Y. State Agricultural Experiment Station.

[2]The writer is indebted to the National Research Council for a grant-in-aid which has made it possible to carry on the work.

tured during these three seasons, covering a wide range of varieties, stage of embryo development, media, pH, and temperature.

Season of 1932:—

Sweet cherry (*Prunus avium* L.):—Early Purple Guigne, Burbank, Coe, Governor Wood, and Downer.

Sour cherry (*Prunus cerasus* L.):—Early Richmond.

Season of 1933:—

Sweet cherry (*Prunus avium* L.):—Early Purple Guigne, Seneca x Early Rivers, Seneca x Emperor Francis, Seneca x Lyons, and Mazzard.

Peach (*Prunus persica* Stokes):—Alexander Crosby, Arp, Belle of Georgia, Carman, Canada, Champion, Chili, Delicious, Eagle Beak, Early Crawford, Elberta, Foster, Golden Jubilee, Krummel, Lola, Morellone, Mountain Rose, North Carolina "Naturals", Rochester, St. John, Troth, Valiant, Veteran, Waddell, and Ward.

Season of 1934:—

Sweet cherry (*Prunus avium* L.):—Seneca, Black Tartarian, Schmidt, Mazzard, and Yellow Spanish.

Sour cherry (*Prunus cerasus* L.):—Early Richmond, English Morello, Montmorency, and Brusseler Braune.

Peach (*Prunus persica* Stokes):—Elberta (New York grown), Rochester (New York grown), Greensboro (Georgia grown), Carman (Georgia grown), Hiley (Georgia grown), Belle (Georgia grown), and Elberta (Georgia grown).

Plum (*Prunus americana* Marshall):—Tecumseh, and DeSoto.

Pear (*Pyrus communis* L.):—Bartlett, Tyson, and Seckel.

Apple (*Malus domestica* Borkh):—Red Astrachan, Early Harvest, McIntosh, Rhode Island Greening, and Rome.

CONTAINERS

Three types of cultures have been used, namely, (a) on agar; (b) in liquid; (c) on sand under a bell jar. Of these three, liquid media has proved least useful. Sand cultures under bell jars have been useful for embryos which have reached nearly full size, but are inadequate for smaller embryos and those which require more time and refined technic for development. For the type of work here reported, agar media has been the most satisfactory, and has finally been adopted as standard.

Various containers have been used. Of these, square screw-cap bottles with aluminum metal caps have proved quite satisfactory. The 1-ounce size is adequate for peaches, and the ½-ounce size is adequate for cherries, apples, pears, and plums, and may be used for peaches, as well. While cotton-plugged containers have been satisfactory in some instances, they offer the disadvantage of more rapid drying out of the medium over a period of weeks or months, and there is more likelihood of contamination from fungi growing through the cotton plug. In White's work in culturing root tips (11), he has found small beakers useful when placed inverted over cotton-plugged Erlenmeyer flasks. Metal capped bottles may be successful in part because the metal cap serves as a protection from external contamination.

CONTAMINATION

Contamination is a serious limiting factor in artificial culture methods but can be controlled with adequate care and proper technique. From several hundred bottles there should be no more than 1 or 2 per cent contamination. Cultures have been maintained free from contamination for as long as 12 months.

While in the usual bacteriological technique, complete sterilization of the container, the medium, and the introduced material may be sufficient, these methods are not suited to embryo culture work wherein the culture may be maintained over a period of weeks or months. The most important considerations in maintaining cultures for a long period of time have been (a) keeping the caps and the bottles, both inside and out, free from any possible media upon which organisms might grow; and (b) placing an inverted cap over the mouth of the container.

Bottles and caps should be thoroughly cleaned with cleaning solution and boiling water, and rinsed in at least three changes of clean, hot water. Not only must the inside of the bottle be clean but also the inside of the cap and the exterior of the bottle, especially at the mouth. Otherwise, after a period of weeks contaminations of molds and other fungi may appear whose entrance is explained by growth of the organisms on the side and mouth of the bottle and under the edge of the cap on media which has not been carefully removed in cleaning, or which has been deposited in filling and handling.

In filling the bottles a pipette is useful, so as to place the media directly at the bottom. Likewise, care should be taken not to slop the media when handling the filled bottles.

Autoclaving at 15 pounds pressure for 20 minutes has been satisfactory. The vials are covered with the caps and the caps screwed down part way before placing in the autoclave. Upon removal from the autoclave the bottles are cooled, and the caps then screwed down tight. If the caps are tightened before the bottles are cooled, a partial vacuum is left so that when the bottles are opened to receive the culture, there is an inrush of air, an added chance of contamination. With media of low agar content (½ per cent) the agar must either be neutralized to prevent hydrolysis and liquefaction at the high temperatures or the bottles must be placed at a low temperature, such as a refrigerator, in order to effect rapid cooling.

DISINFECTANTS

Many disinfectants have been used and at various concentrations. Excellent results have been secured with calcium hypochlorite as used by Wilson (12) and Knudson (3).[3] Soaking tests made at various intervals of time from 15 seconds to 30 minutes show that 3 minutes is sufficient to accomplish sterilization and that embryos will stand 5 minutes and more without injury. In routine work, there-

[3]A 2 per cent chlorine solution is made by shaking 10 grams of calcium hypochlorite in 140 cc of water and filtering. The filtrate should have a slight straw color. Commercial chloride of lime is satisfactory. Such a solution which measures almost exactly 20,000 p.p.m. (2 per cent) has been used with satisfactory results for a period of 7 days when kept in a refrigerator.

fore, 5 minutes in a 2 per cent chlorine solution has been accepted as standard and used with excellent results. Stender dishes with covers are useful in which to treat material with calcium hypochlorite. The volume of liquid used should be 5 to 10 times that of the material. The container should be shaken frequently so as to remove air bubbles and to insure contact with the entire surface of all embryos.

Other materials have been used with varying results. Some samples of a commercial brand of sodium hypochlorite gave satisfactory disinfection when used one part to two of water; while other batches of the same material gave poor sterilization and some injury. It has been reported that in some instances this material may run as high as 15 or 16 per cent sodium chloride and may otherwise be variable so that its use has been discontinued and is considered treacherous in work of this kind.

Washing in Sterile Media and Water

Since there is a question whether treating embryos with a disinfectant may affect the performance, tests were run in which some lots were washed in sterile water following disinfecting, other lots were washed in sterile liquid media, and other lots were placed in the containers without washing. There has seemed to be no advantage to the cultures in the added step of washing, and the percentage of contamination has been increased. Accordingly, no washing has been used in the standard routine in this work.

Transfer

In transferring the embryos from the calcium hypochlorite solution, wire loops set in glass rods have been most satisfactory. Tweezers, section lifters, and other instruments may be used, but best results are secured by making a wire loop slightly smaller than the embryo, shaping the loop to suit each batch of embryos. The regular bacteriological routine is followed in which the loop is flamed and plunged red into the calcium hypochlorite solution. The liquid cools the loop sufficiently so that no injury is done to the embryo, which is then placed in the bottle with an adhering film of the hypochlorite solution. The amount of hypochlorite solution introduced with the embryo has no apparent harmful effect, while the film of solution aids in preventing contamination in transfer.

In introducing the embryo a good plan is to first loosen the bottle caps. Then, grasping the bottle in the left hand, the cap may be twisted off between the thumb and index finger of the left hand and held at an angle over the mouth of the bottle. The bottle may then be tipped to near the horizontal and the embryo introduced on the wire loop held in the right hand. By this method the bottle is open a minimum of times and the cap serves as a protection to contamination from the atmosphere. Good results have been secured without flaming the bottles.

The caps may be screwed tight at once, or not. Batches have been cultured successfully with (a) caps screwed tight immediately after introduction of the embryo, (b) caps left loose and then tightened, and (c) caps left loose. There seems to be no harmful effect from

screwing the caps tight at once. With caps slightly loose, contamination has on some occasions been greater, such as during a period of dry weather with high winds.

A transfer room is desirable but has not been found necessary. In this work, one laboratory room has been used for preparation of material, and a second for transfer. Washing the table tops and otherwise maintaining the laboratory clean and free from dust and organisms are helpful practices.

Removing Embryos from the Fruits

As fruit is brought into the laboratory it is well to wash it, and otherwise take such precautions as to reduce the chances of introducing foreign organisms into the laboratory. A little practice will indicate that there are various methods of removing the embryo, depending upon the particular fruit and the stage of development. With the cherry, pits can be opened without injuring the embryo if the pits are placed on a block at an angle of about 45 degrees, with the ventral suture uppermost and the stem end downward. Then, by pressing downward at the stem end with a scalpel or sharp knife, the pit will split in the majority of cases, exposing the enclosed seed without injury. With peaches and pits heavier than cherry, the pit may be placed ventral suture uppermost on a wooden block, and cracked by striking with the rough surface of coopers' hatchet.

Pear and apple seeds are difficult to hold unless the mucilaginous coating is first removed from the seed coats. Dipping in calcium hypochlorite tends to remove this slippery coating, and makes the seed easy to handle. In removing the integuments, a cut from the chlazal end halfway down the side with a sharp scalpel will open the integuments sufficiently so that with slight pressure between the thumb and index finger the embryo can be squeezed out without injury. With mature seed, which has been dried, it may be necessary to soak over night to loosen the integuments.

Stage of Embryo Development

The stage of development of the embryo when removed from the fruit is a limiting factor in the use of artificial culture methods with present technique. Following fertilization, the embryo of the apple, pear, peach, cherry, and plum enlarges very slowly for a considerable period of time (17 days for the sweet cherry, 21 days for the sour cherry, and 49 days for the peach), and then develops rapidly to maximum size (6, 8, 9). In the case of the stone fruits, this rapid enlargement of the embryo coincides with the period of arrested development of the pericarp and the attainment of maximum size by nucellus and integuments (6, 8, 9). Attempts to culture embryos in the early stages of development following fertilization have so far not met with practically useful results.

During the period of rapid enlargement of the embryo, however, embryos either removed from the fruit or aborted during this period may be cultured artificially with varying success, depending upon the stage at which they are removed or aborted. Best results have been secured with embryos which have been removed or aborted at the

attainment of nearly maximum size characteristic of the variety. For example, with a variety of cherry in which the embryo normally reaches approximately 6 mm in length, best results are secured with embryos 5 to 6 mm in length. With cherry embryos under 3 mm in length the percentage of successful cultures has been small. With embryos 3 to 4 mm in length, a fair proportion may be expected to develop into plants.

Seedlings show anomalous growth characters which are more or less characteristic of the stage of development at which the embryo was aborted or removed. For example, cherry embryos 3 mm in length may develop chlorophyll in the cotyledons, hypocotyl elongation of 2 to 4 mm, and an epicotyl rosette of small white leaves, but fail to develop into normal plants. Embryos a little larger and further developed when cultured, may produce normal roots and an epicotyl of 6 to 8 mm in height terminated by a rosette of green leaves. Embryos still larger and still further developed when cultured may produce normal roots and a stem axis 3 to 5 cm in height but with anomalous leaves. Still later stages, as embryos reach near maximum size, may be found to develop well but with occasional anomalous leaves and peculiar terminal rosette formation. These plants may later develop normally when properly handled.

From the practical viewpoint of securing as many plants as possible from artificial cultures, the best stage of development to remove embryos is when the fruit is ripe. There are undoubtedly exceptions to this general statement, but this rule will be found helpful. Even the embryos of early ripening varieties of cherries, such as Early Purple Guigne, need not be removed until the fruit is ripe, since the embryos do not disintegrate immediately after they abort.

Media

Both liquid and agar media have been used, of varying agar and salt concentration, glucose content, and pH. In general, with the exception of a few embryos in flowing medium, embryos submerged in liquid media have shown no enlargement and fail to develop chlorophyll. Moreover, contamination is more likely because of splashing or slopping of media against the cap or mouth of the bottle while handling, thus allowing organisms to grow from the outside down onto the embryo.

Agar concentration:—Agar has been used ranging from ½ to 10 per cent. Although some favorable results have been reported with embryos of Iris (10) using 10 per cent agar, it has been found very difficult to make an agar medium of such high concentration. Furtheremore, embryos have failed to develop as uniformly as in lower concentrations. One and 2 per cent concentrations have given good results, but the percentage of favorable cultures has been highest in 2/3 per cent agar. At this concentration the agar is sufficiently stiff to support the embryo on the surface, yet the availability of water does not become a limiting factor as it appears to be with very high concentrations.

Salt concentration:—Satisfactory growth has been secured with various salt solutions, such as (a) used by Robbins (4) in root cul-

tures; (b) used by White (11) in culturing root tips, with and without yeast extract; (c) Crone's modified; and (d) Knopf's solution at dilutions used in sand cultures. Concentrations have been varied from 1 to 10 times, with no appreciable effect upon embryos or seedling development so long as the concentration did not exceed that toxic to the plant.

Importance of glucose in the media:—The presence or absence of glucose in the medium has had an important influence upon the development of embryos. Other carbohydrates might be expected to give similar results but have not been fully tried. With embryos removed from the fruit at very early stages of development, the absence of glucose in the medium has resulted in no chlorophyll formation and no development of the embryo; while addition of 1 per cent glucose to the medium has resulted in moderate chlorophyll accumulation and embryo development, and 2 per cent glucose has resulted in abundant chlorophyll accumulation and conditions favorable to rapid embryo development.

On the other hand, more fully developed embryos removed from the fruit at later stages of development, are noticeably inhibited by glucose in the medium and favored by its absence. A 2 per cent glucose concentration is strongly inhibiting, a 1 per cent glucose is slightly inhibiting, and a ½ per cent glucose but very slightly inhibiting.

For a general purpose medium, therefore, to cover the range of early and late embryos, it has been found that ½ per cent glucose is sufficient to favor chlorophyll formation in early embryo stages, yet is only slightly inhibiting in late stages.

pH of the media:—Embryos have been cultured in media ranging from pH 3.8 to 8.6, using Zinzadzé's (13) constant pH formulae, with no appreciable effect of pH upon percentage development. The general purpose formula given in the following paragraph and used in these tests as standard has a pH of about 5.5. A lower pH increases the possibility of hydrolysis of agar during sterilization and cooling while higher pH reduces or eliminates it. With the 2/3 per cent agar used in these studies as standard, it is necessary to make the period of sterilization and cooling as brief as possible, to avoid hydrolysis and liquefaction.

General purpose media:—From these studies the following general purpose formula (2/3 per cent agar and ½ per cent glucose) has been developed which has been used with satisfactory results for excised embryos of apple, pear, peach, cherry, and plum over a wide range of embryo development.

Grind and mix:

10 grams	KCl	To 1½ grams of this salt mixture, add 6½ grams of agar, 5 grams of glucose, and 1 liter of water.
2½ grams	$CaSO_4$	
2½ grams	$MgSO_4$	
2½ grams	$Ca_3(PO_4)_2$	
2½ grams	$FePO_4$	
2 grams	KNO_3	

One of the conveniences of this mixture is that the salts may be ground, thoroughly mixed, placed dry in a stoppered bottle, and used over a period of months as needed. In making the media weigh out 1½ grams of the powdered material and place it, together with 6½ grams of agar, in 1 liter of water, and heat until the agar has dissolved. There may be a slight cloudiness to the mixture, but there seems to be neither advantage nor disadvantage in filtering, since the slight cloudiness has not been found to be a limiting factor.

Culture Room

A satisfactory culture room is a room with normal daylight. Cultures have been made under various conditions, such as, in controlled temperature cases at varying temperatures, in direct sunlight, with and without artificial light, in the dark, and in various combinations of these factors. Good results have been secured with shelves built in a north window of a laboratory. If a south or east window is used, the problem of shading is introduced, since direct sunlight raises the temperature within the bottles to a point where it sometimes becomes injurious. Lacking a north window, a table placed a short distance from the window out of direct sunlight has also proved satisfactory. Embryos have been cultured at room temperatures, ranging from 50 to 90 degrees F and with fluctuating day and night temperatures.

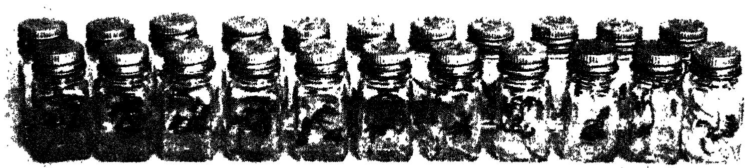

FIG. 1. Sweet cherry seedlings in 2/3 per cent agar culture in ½-ounce bottles. August 16, 1934 (100 per cent stand).

FIG. 2. Peach seedlings in 2/3 per cent agar culture in ½-ounce bottles. August 31, 1934 (100 per cent stand).

Transfer to Pots

When the plants have developed normal root and top growth they can be shaken from the bottle together with the agar and transplanted without injury. Plants have, however, been grown in bot-

tles for 4 months by removing the caps when the plants have reached the top of the bottle, and adding water as needed. Best results have been secured by first transplanting into sterile quartz sand in 1½-inch pots and watering with one of the standard nutrient solutions until the plants are sufficiently large to shift to soil in larger pots. Following both transplanting operations the seedlings have been gradually "hardened". Good results have been secured after removal from the bottles by covering closely above and on the sides with cheese cloth, or by placing under a bell jar and gradually increasing the air over a period of a week to 10 days. When the plants are larger and are shifted to larger pots, a box-like hood of moist cheese cloth fitted over the greenhouse bench has given good protection.

FIG. 3. Peach seedlings from artificial culture season of 1934.

REST PERIOD

Non-after-ripened embryos cultured by this method have frequently developed to a stage characteristic of the size of embryo cultured and then entered a period of arrested growth or dwarfing. This situation has already been reported upon by Flemion (2) and by Davidson (1). Plants maintained at a growing temperature of 65 to 75 degrees F have remained dwarfish, but those removed to a cool place, such as a nursery cellar with a temperature of 40 degrees F for 6 to 8 weeks, have developed rapid normal growth when returned to temperatures of 65 to 75 degrees F in the greenhouse.

Using these methods, cherry and peach seedlings have been raised, transplanted, and moved to the field where they are now 2 and 3 years old.

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The Influence of Pulp Disintegration Upon the Viability of Peach Seeds

By I. C. HAUT, *Oklahoma A. and M. College, Stillwater Okla.*, and F. E. GARDNER, *U. S. Department of Agriculture, Washington, D. C.*

IT is a rather common practice in securing the seeds of peach, plum, and cherries, to place the fruit in piles until a convenient time for the removal of the pits or purposely to delay removal until sufficient disintegration of the pulp has occurred to allow easier separation from the seed. Nurserymen also frequently secure peach pits for the propagation of seedling stocks from canning factories, where the pits are allowed to remain in piles for varying lengths of time. Cull fruits from which the pulp has been permitted to disintegrate are likewise often utilized as a source of seed. Believing the low percentage germination sometimes obtained by nurserymen with peach seed may possibly be due to injury during its procurement, data are presented in this paper showing the relationship of treatment to the viability and subsequent germination in peach seeds.

During the summer of 1932 approximately 20 bushels of Elberta peaches were placed in a pile and allowed to disintegrate. A thermometer was placed near the center of the pile and the temperature recorded daily, the highest temperature observed being 34 degrees C on the sixth day. One lot of seeds was removed prior to the beginning of disintegration (check lot), a second sample after 5 days in the pile, and a third sample 7 days following the second. Following removal from the pile the pits were washed, allowed to dry in a cool place and stored dry until planted in the nursery on November 2. Eight hundred pits were planted from each lot, the pits being placed in rows and covered to the depth of 2 inches. The following spring germination counts were made. Germination of 27.0 per cent was obtained for the check lot; 0.88 per cent for the second lot following 5 days of disintegration; and 0.13 per cent for the third lot allowed to decay for 12 days. Even though the percentage of germination obtained with the check lot was relatively low, the results clearly indicate that even 5 days of pulp disintegration results in marked reduction of viability of the seeds.

Since the results of this simple test have such an important practical aspect it seemed desirable to carry the investigation further, using seeds of some variety having a higher percentage of viable embryos than is the case with Elberta which usually results in relatively poor germination. Accordingly, in 1933 a large quantity of fruit was obtained from seedling cling peach trees known to possess unusually high seed viability. At the time of picking, seeds were removed with considerable difficulty from fruits which were still hard and green; another sample from fruits of edible ripeness; and a third from peaches which were very soft but not rotted. The remainder of the crop was placed in a large pile and allowed to decay. During this disintegration period daily temperatures at the middle of the pile were recorded.

At intervals of 2, 3, 4, 6, 8, and 10 days during the decomposition period, samples of pits were removed for subsequent observation and germination studies. Immediately following removal the pits were washed and placed in moist sand in common storage. In January, 200 pits from each lot were removed and cracked in order that examinations could be made on the number of apparently sound seeds in each treatment. The remaining seeds from each lot were allowed to continue their after-ripening process until April when they were sown in flats of sand in order to obtain germination records. The results of both the examination and germination tests are presented in Table I.

TABLE I—EFFECT OF DECOMPOSITION OF PEACH FRUITS WHEN PILED, UPON THE APPARENT VIABILITY AND GERMINATION OF THE SEEDS

Condition of Pulp	Temp. at Center of Pile (Degrees C)	Examination Results		Germination Results	
		No. Seed Cracked	Cracked Seed Apparently Viable (Per cent)	No. Seed Planted	Germination (Per cent)
Green	—	200	100.0	510	92.6
Ripe	—	200	100.0	516	86.3
Soft	—	200	100.0	424	83.3
Decomposed for					
2 days	33	200	93.3	212	69.8
3 days	34	200	87.5	287	67.2
4 days	44	200	68.5	315	53.0
6 days	44	200	66.0	202	47.0
8 days	31	200	70.0	298	18.1
10 days	32	200	66.5	312	14.7

Temperature on fifth and seventh days of decomposition was 44 and 41 degrees C, respectively.

The results presented indicate that as the length of the decomposition period increased the germination percentage progressively decreased. Whereas 83 per cent germination was obtained with seed taken from soft fruit, only a 14 per cent germination was obtained following ten days of decomposition in the pile. Even 2 days of decomposition resulted in a marked reduction in ability to germinate.

Conceivably, sufficient heating to cause injury to the embryos may result from piling fruit (2), yet the highest temperature recorded within the pile in the first experiment was 34 degrees C. This was attained on the sixth day of decomposition, while the results of the subsequent germination tests showed practically complete loss in viability had already occurred before this maximum had been reached. The highest temperature in the second experiment was 44 degrees C., attained on the fourth day of decomposition, whereas the subsequent germination tests again indicated that considerable injury had occurred before the maximum had been reached. If heating in the pile accounts for all of the injury apparently sustained, it is difficult at the present time to account for the progressive reduction in germination between the green, ripe and soft lots.

It is evident from the examination of cracked seeds (Table I) that the status of viability cannot always be accurately determined by

observation. Many of the seeds seemingly uninjured by the treatment did not prove viable in the subsequent germination tests. Due to the low temperature during the after-ripening period the injury sustained in the pile did not become apparent until rotting of the seeds was hastened by the warmer temperature of germination.

In 1934 further studies were made with the object of determining what might be the causal factor during the period of decomposition accounting for this loss of viability. In addition to actual injury due to high temperature as one possibility, it was decided to test also the juice from the decomposed pulp for evidences of toxicity due perhaps to acidity or alcohol content developed in the natural processes of fermentation. For this work, ripe fruits were harvested from the same cling peach trees which served in the preceding experiment.

The fruit was divided into two portions. The peaches from one portion were spread out in a single layer and allowed to decompose individually in order to avoid the generation of a high temperature. At intervals of 5, 8, 10, 14, and 17 days, respectively, during decomposition random samples of 100 seeds each were removed, washed clean and stored in moist sand.

From the second portion of fruit the seeds were separated from the pulp at once prior to any decomposition. The pulp, however, was saved and allowed to decompose for 1 week after which time the juice was expressed and allowed to ferment for 7 days more. The pH of the juice was determined by the quinhydrone method to be 3.5. The total titratable acidity, electrometrically determined, was found to be .32 of normality.

Seeds from the second portion of fruit were subjected to a series of soaking treatments of 8 days duration. One hundred seeds were used for each of the following treatments: (1) Juice, pH 3.5; (2) juice, neutralized with NaOH; (3) acetic acid, pH 3.5; (4) ethyl alcohol in concentrations of 2, 5 and 10 per cent; (5) water, at room temperature (check treatment); and (6) water at three higher temperature conditions, namely, 36 to 40 degrees C, 43 degrees C, and 52 to 56 degrees C.

Following these treatments the seeds were again washed, placed in moist sand and, along with those seeds from the pulp decomposition series, were placed immediately in cold storage at 1 to 2 degrees C

TABLE II—EFFECT OF DECOMPOSITION OF PEACH FRUITS WHEN NOT PILED, ON THE VIABILITY AND GERMINATION OF THE SEEDS (100 SEEDS IN EACH TREATMENT)

Condition of the Pulp	Germination on Dec. 20, 1934 (Per cent)	Apparently Viable but not Sprouted, Dec. 20 (Per cent)	Germinated Apparently Viable Seed (Per cent)
Check—no decay	51	42	93
Decomposed for:			
5 days	55	36	91
8 days	36	49	85
10 days	48	47	95
14 days	60	11	71
17 days	64	25	89

TABLE III—EFFECT OF VARIOUS SOAKING TREATMENTS ON THE VIABILITY AND GERMINATION OF PEACH SEEDS (100 SEEDS IN EACH TREATMENT)

Materials and Temperatures for 8-Day Soaking	Germination on Dec. 20, 1934 (Per cent)	Apparently Viable but not Sprouted, Dec. 20 (Per cent)	Germinated and Apparently Viable Seed (Per cent)
Water, room temperature	41	53	94
Juice, pH 3.5	0	0	0
Juice, neutral	0	0	0
Acetic acid, pH 3.5	43	52	95
Water, 36 to 40 degrees C.	0	0	0
Water, 43 degrees C.	0	0	0
Water, 52 to 56 degrees C.	0	0	0

for 9 weeks to after-ripen. Following the after-ripening period, the seeds were sown in flats of sand in a warm greenhouse for germination, on Nov. 5, 1934. The results are presented in Tables II and III.

By December 20, the rate of germination had slowed down to a standstill. At this time, all seeds still not germinated were cracked and examined. In the case of the juice and the hot water treatments the seeds, having been injured by the treatments, had all badly decayed. With all other treatments, however, the majority of the seeds were sound and bright. Their failure to germinate was evidently not due to injury but perhaps to insufficient after-ripening. For this reason, they are added to the number germinated in the last column of Tables II and III which, it is believed, presents a more accurate account of the effect of prior treatment than the partial germination in the first column.

The results of the alcohol treatments have been omitted from Table III. Germination in these lots was so markedly delayed that the pits were at length artificially cracked to determine whether the seeds had been injured by the treatment. The subsequent examination disclosed that all seeds were sound and apparently viable. When again placed in the sand without their endocarps they began to germinate promptly. Although this shows that the alcohol treatments were not injurious, the seeds unprotected by the endocarps were molested by mice before examination was completed and as a result, final averages were not obtained.

The results in Table II show no consistent evidence of injury to the seeds following decomposition in a single layer, i. e., without the generation of heat. Moreover, even the moderate temperature of the 36 to 40 degrees C water bath completely killed all seeds. These two findings in themselves seem to point to high temperature as the deleterious factor shown in Table I where the fruit was decomposed in a pile. However, results from the juice treatments presented in Table III indicate that there may be still another factor, namely, that of some toxic effect from the juice exclusive of the acidity or alcohol concentration.

This may possibly account for the progressive reduction in germination shown in Table I between green, ripe, and soft fruits. The number of seeds involved in these tests makes the factor of chance reduc-

tion improbable. In this connection it has been reported that stratifying the seeds of certain fruits without removing the pulp may result in decreased germination (1).

Certain practical recommendations when procuring peach seeds can be made, based on this work. Although a certain stage of pulp decomposition greatly facilitates the separation of the seed such decomposition should be accomplished in a single layer to avoid the generation of heat and should be restricted to as short a period as feasible in order to minimize the possible effect of some toxic property of the juice of the decomposing pulp.

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Ring Grafting and Stock Effect[1]

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IT has been clear for several seasons that stock effects upon the growth of a scion variety could be said to be largely caused by the stem portion of the stock (1). At least, they can be produced by double-working, i. e., the grafting of a piece of stem of the stock variety between a scion and a seedling piece root (2). It has been repeatedly noted from histological observations that trees of a variety grown upon different stocks accumulate carbohydrates very unequally. The analytical work of Colby (3) appears to show that trees of a variety on different stocks may have a like mineral content although growing unequally. It appeared then, that stock effects were not due to qualitative differences in mineral uptake of the roots, but possibly to a difference in transport (unless the rate of photosynthesis of a scion variety is modified by the stock and so, responsible for the rate of carbohydrate accumulation in the top).

The question arose, then, of what effect a ring of bark grafted upon a shoot would have upon the subsequent growth of the shoot[2]. In other words, would a ring of bark produce a "stock effect?"

To test this idea, 1-year nursery trees were cut back to a height of about 8 inches; and, shortly after the bark would slip readily, rings

Fig. 1. Ring grafts on nursery trees. Some variety combinations form rather smooth unions, others have prominent callus formations at one or both edges of the ring. The unequal increase in diameter of stem and ring variety is typical. Left to right: Transparent on self, Snow on Y. Siberian, Malling XII on Winesap, Snow on Winesap, Malling IX on Whitney, Whitney on self.

[1]Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.

[2]A modification of a suggestion made by Dr. E. J. Kraus, University of Chicago.

of bark from various sources were grafted on at about 5 inches above the ground. These were tied with string and covered with grafting wax. The space for the ring was made by cutting out a ring of bark about ⅞ inch wide with a "pecan budding knife." The appearance of the grafts at the close of the growing season is shown by Fig. 1.

Some varieties as York gave poor stands of grafts apparently as a result of the excessive heat and dry weather shortly after the grafting was done. With other varieties sufficient numbers survived to give the data of Table I. The size of the nursery tree one season greatly affects its growth the next year (2), and should be considered when recording the subsequent growth of the tree. The growth of the grafted trees and the checks is expressed as ratios of the amount of growth made in the two seasons; the length in 1934 being divided by that of 1933.

TABLE I—Ratio of Growth in 1934 to Growth in 1933 Ring Grafted Nursery Trees

Ring Variety	Stem Variety		
	Whitney	Winesap	Transparent
Ungrafted	1.54±.08	1.22±.20	1.54±.04
Self	.74±.10	——	1.32±.08
Malling IX	1.21±.13	——	——
Malling XII	1.65±.06	.86±.07	——
Yellow Siberian	1.37±.09	1.53±.21	——
Tetofsky	1.30±.09	——	1.14±.07
Snow	——	——	1.42±.09

These preliminary data indicate an unequal effect from the rings. As with double-worked trees, the different "stocks" had unlike effects upon different scion varieties. It is of particular importance from the standpoint of the technique used that some graft combinations resulted in as much or more growth than was made by ungrafted trees. The unequal effect of grafting the varieties with their own bark is typical of the unequal responses from other cultural treatments.

The new xylem formed under the ring of bark appears to vary in character in different combinations being like the ring variety, like the stem variety, or in some cases resembling neither. The accumulation of starch in the tissues above the rings appears to bear a very significant relation to the amount of growth made by the new shoots. It is hoped these and correlated items will be found to offer some explanation of the fact of the variable reactions of varieties to a single stock.

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Three Apple Stocks Especially Well Adapted to the Practice of Double Working[1]

By T. J. MANEY, and H. H. PLAGGE, *Iowa State College, Ames, Ia.*

THE extensive winter injury which occurred on apple trees in the Eastern states during the winter of 1933–34 is only a repetition of conditions which have been experienced quite frequently during the history of fruit growing in the Upper Mississippi Valley. This region is characterized by winter temperatures as low as –30 to –40 degrees F, light snow cover, deep freezing of the ground and high northwest winds which singly or in combination cause severe damage to tender and half hardy varieties. In Iowa and most other states of the Upper Mississippi Valley as well as Canada, where winter injury is the limiting factor of successful orcharding, topworking on hardy stocks is practiced as one method for increasing the hardiness of the best commercial varieties like Jonathan, Grimes, and Delicious.

It is an open question as to whether a tender variety is rendered more cold-resistant by topworking it on a hardy stock. Hardiness is but a relative term. In a broad sense it is the ability of a plant to withstand adverse conditions of climate, neglect, insect and disease attack, etc. At any rate, there is evidence to show that certain hardy stocks may extend the life of a less hardy top and this is the fact which is of most importance to the fruit grower.

Some information which has a direct bearing on the above question is available in the records taken in the orchard of W. P. Campbell of Woodbine, Iowa. This 20-acre orchard was planted by D. W. Lotspeich in 1893–1894. Grimes, Gano, and Jonathan were planted as root grafts on French Crab stock and the same varieties were also trunk grafted on 2-year-old root grafted stocks of Virginia Crab, Haas and Sheriff.

In 1914 a record of the condition of all the trees in the orchard was made, and again in 1934 another condition record was taken. Table I indicates quite clearly that the use of the double worked stocks Virginia Crab, Haas, and Sheriff has prolonged the life of Jonathan, Grimes, and Gano over the same varieties root grafted on French Crab. The data are of particular interest in respect to Gano. In southwestern Iowa, where thousands of these trees existed 25 years ago, now only comparatively few old trees remain. The majority of the trees died during the period of 1910–20 as a result of drouth, over-production, and winter injury, which weakened the trees and rendered them susceptible to the attacks of blister canker. It is of interest to note that during the 40 years' history of this orchard the surviving trees have experienced all the vicissitudes of Mid-western climate, ranging from intense drouth and summer heat to winter cold of –40 degrees F.

In the Campbell orchard there are topworked trees of Grimes and Jonathan which produce 30 to 40 bushels per tree in crop years. Some of the outstanding trees are those worked on Haas and Sheriff.

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TABLE I—RECORD OF TOPWORKED APPLE TREES IN W. P. CAMPBELL ORCHARD, WOODBINE, IOWA. ORCHARD PLANTED BY D. W. LOTSPEICH, 1893–94

Variety and Stock	Trees Alive 1914	Trees Alive 1934	Percentage of Trees Alive 1934
Grimes on French Crab	72	3	4.0
Grimes on Virginia Crab	22	16	72.0
Grimes on Haas	135	52	38.0
Grimes on Sheriff	9	7	77.0
Gano on French Crab	84	3	3.5
Gano on Sheriff	37	26	70.0
Sheriff on French Crab	108	66	61.0
Jonathan on French Crab	113	30	26.0
Jonathan on Virginia Crab	13	7	54.0
Jonathan on Haas	44	36	82.0
Jonathan on Sheriff	2	2	100.0

Observations and replies to questionnaires assembled by the Pomology Subsection of Iowa Agricultural Experiment Station over a period of years indicate that the varieties which are outstanding stocks for topworking are Virginia Crab, Hibernal, and Haas. Sheriff has not been used to any extent, but its performance in the orchard at Woodbine indicates that it has outstanding possibilities for stock purposes.

HIBERNAL

This variety is one of the Russian importations sent to the United States Department of Agriculture in 1870 by Dr. Regeler of St. Petersburg. It is considered the hardiest of all the large fruited apples of *Pyrus malus*.

Distinguishing characteristics:—The branches make nearly 90-degree angles with the trunk. Bark chocolate brown; leaves large, roundish, quirked at tip, upper surface rugose, wrinkled, edges waved; serrations regular, medium in depth; pubescence very heavy on under side of leaf. In the nursery this variety might be confused with Oldenburg, but it is distinct from this variety in its wide-angled crotch structure, and thick heavy leaves of a lighter shade of green than those of Oldenburg. Its foliage is outstanding in comparison to any other common variety.

HAAS

This variety is a vigorous grower with long, slender branches which make rather narrow-angled crotches with the trunk. Bark dark green with a greyish scarf skin; leaves large, dark green, edges wavy; serrations fine, compound. It would be rather difficult to identify nursery mixtures in this variety by leaf characters alone, but it could be distinguished from other varieties by its long, slender branch formation.

VIRGINIA CRAB

This variety as grown in the Middlewest must not be confused with the Hewes' Virginia Crab or seedlings grown from this variety. The Hewes' Virginia was first described by Coxe (1) in 1817.

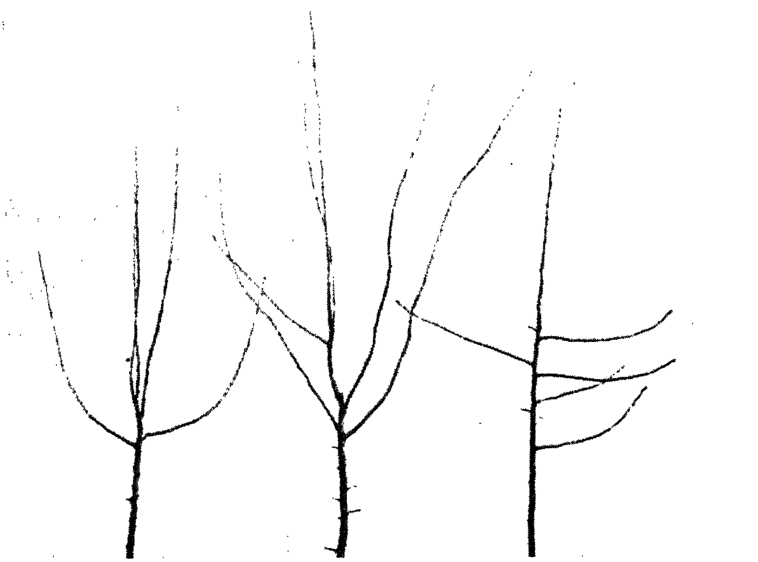

FIG. 1. Left to right, Virginia Crab, Haas, and Hibernal. The branching characteristics of each variety is a good means of identification.

The Virginia Crab now grown throughout the Middlewest originated in the nursery of Suel Foster, Muscatine, Iowa. It was pointed out to Mr. Foster by N. K. Fluke as a mixture in a lot of Hewes' Virginia Crab. While the literature (2) makes this statement, it is otherwise understood that it was selected as a variation in a lot of seedlings of the Hewes' Virginia. Mr. Fluke sets the date of its origin as 1862 (3). In 1888 (4) he stated that his orchard trees of the variety planted in 1866 were 4 feet in circumference. For years Mr. Fluke was a prominent fruit grower at Davenport, Iowa, and was largely instrumental for the introduction of the Virginia Crab as a stock.

The tree of this variety is very vigorous and has a wide-spreading form. On young trees the bark is olive green, covered on 2-year and older wood with a characteristic greyish netted scarf skin. The branches are heavily shouldered and form nearly 90-degree angles with the trunk but grow out horizontally for 6 to 12 inches and then turn sharply upward. The limbs seldom split down from fruit loads or ordinary causes. These characteristics distinguish the variety from almost any other common crab variety. The leaves are thick, leathery, distinct olive green, smooth upper surface, long, medium width, folded upward, pubescent beneath; serrations very distinctive, sharply serrate, nearly dentate; stipules very long, persistent; veins heavy.

Attention has been called to the possibility of the existence of certain strains in the variety. The writers have been familiar with the variety for at least 20 years and have never noted any variation in

the type but have found various mixtures of it and other varieties in the nursery and orchard plantings, such as *Pyrus baccata,* Yellow Siberian, Shields Crab, etc. These or other crab mixtures are easily separated from the true Virginia by their lighter colored bark and leaves and sharp-angled crotches. Practically all references to Virginia Crab indicate that it is highly resistant to blight in trunk and branches. The writers have never observed blight in the variety in any age of tree.

The foregoing stocks in general make good unions with the common commercial varieties. Virginia slightly overgrows the topworked variety. Hibernal makes fine unions with Grimes, Jonathan, and Delicious. The union of Haas with Jonathan and Grimes is often so smooth that the line of separation is scarcely distinguishable.

Topworking on Virginia and Hibernal should be done on the branches in order to take advantage of the splendid limb structure of these stocks. The best practice of double working is to plant 2-year-old root grafted trees, allow them to grow for 1 year in the orchard, and then bud in the branches. Haas has sharper angled crotches but with age develops a widespreading tree. It makes an excellent stock when stem worked.

Virginia, Hibernal, and Haas, together with Sheriff, deserve the careful attention of Eastern and other fruit growers who are setting out new or replanting old orchards. From the general experience of fruit growers in the Middlewest it is evident that topworking on hardy stocks is conducive to vigor, productiveness, disease resistance, and long life in the topworked variety.

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A Study of the Root Distribution of Stayman Apple Trees in Maryland

By P. C. Marth, *University of Maryland, College Park, Md.*

THIS work was carried on in connection with nitrogen fertilizer studies to determine the relative concentration of so-called "feeding roots" as well as other roots in the upper foot of soil in concentric areas under the spread of the limbs. The responses in growth and fruiting to nitrogen applications in this areas, can be interpreted more accurately when such data are available.

Description of Orchards

This study on mature apple trees was undertaken in Maryland in the spring of 1931 and again in 1932. In order to study the possible effect of different soil types, and varying soil management methods on the root system developed, three orchards located in different parts of the state were used as follows:

1. *The Messick Orchard, (Orchard A)*:—This orchard is located in the coastal plain area at Hebron, Maryland. The Stayman trees in this orchard were about twenty years old, and were growing on a loose, sandy, loam soil, which had not received cultivation for the previous 5 to 6 years. Native grasses and weeds mowed at varying intervals during the growing season had formed a loose sod overlaid by a weed mulch. The root systems of seven trees were studied.

2. *The Harrison Orchard, (Orchard B)*:—This orchard is located in the coastal plain area at Berlin, Maryland. The Stayman apple trees used were about 20 years old and were growing on a clay loam interspersed with sandy loam somewhat heavier than found in the Messick orchard. The Harrison orchard had received a shallow plowing, and was disced each year until the latter part of July, when a rank crop of native weeds was allowed to grow. The root systems of six trees were studied.

3. *The Caspar Orchard at Hancock, Maryland, (Orchard C)*:—This orchard is growing on a loose limestone, shale soil with a clay loam soil mixed with the shale. The trees of the Stayman variety were about 25 years old and had been growing in a sparse alfalfa sod for several years previous to the study. The root systems of two trees were studied.

Method of Sampling Roots

The method of sampling roots was uniform for all of the 15 trees used. A root sampling tool was constructed of 1/16-inch sheet metal exactly 1 foot square and 6 inches deep, and sharpened at the base. This implement was driven into the soil with a wooden mallet, cutting off and enclosing all roots within a square foot of soil to a depth of 6 inches. The enclosed soil and roots were then lifted out intact, and laid on a wire screen. The implement was then driven into the soil in a position exactly below where the first 6-inch sample had been removed. The enclosed soil and roots again were laid out on another wire screen. In this way a square foot of soil was sampled to a depth of 1 foot. This procedure also made it possible to measure separately the roots in the first and second 6-inch layers.

In order to sample the roots of each tree thoroughly the area be-

neath the tree was laid off into concentric 3-foot circles, with the tree trunk as the center. The following samples were taken from each circle, beginning at the tree trunk and working outward: (1) 0–3 feet, three samples, (2) 3–6 feet, four samples, (3) 6–9 feet, five samples, and (4) 9–12 feet, six samples. The area within each 3-foot circle was sampled in such a way that the samples were staggered about the tree as the sampling progressed outward away from the tree trunk. A total of seventeen samples each of the first and second 6-inch layers of soil was taken per tree.

Each sample was carefully screened to remove the bulk of soil, then brought into the laboratory and washed free of adhering soil particles. The superficial moisture was dried off at room temperature and the roots then separated into the following sizes: ½ to 1 inch, ¼ to ½ inch, ⅛ to ¼ inch, 1/16 to ⅛ inch, and fibrous roots. The roots in each lot were counted, weighed and measured. Particular attention was given to collecting the fine fibrous roots, which were weighed separately in each instance. It was felt that these very small roots, with their numerous root tips, function very actively in water and nutrient absorption, and are of very great importance to the tree from this standpoint.

Discussion of Results

The figures presented in Table I are calculations of the total roots in the upper foot, based on the root population in the concentric areas sampled about the tree. Calculations were made for each tree studied and the average for the different orchards are presented here. The data showing individual root size have been omitted. However some idea of the sizes encountered may be obtained by comparing columns headed "Number of Roots" and "Weight of Roots," contained in Table I.

The number of roots found in the surface foot of soil varies considerably with the soil type encountered and the cultural treatment the orchard has been receiving. In orchard A the greatest total root content was found from 6 to 9 feet from the tree trunk, over two-thirds of the roots in this area being in the upper 6-inch layer of soil. In orchard B, where cultivation has been employed, the maximum number of roots was also in the 6- to 9-foot area, but here the roots were concentrated in the second 6 inches of soil. In the heavier soil found in Orchard C, the greater number of roots was found closer to the tree trunk in the 3- to 6-foot area; here also the tendency was for greater concentration of roots in the upper layer of soil. At greater distances from the tree trunk the differences between the number of roots in the upper and lower 6 inches of soil tend to be in favor of the lower depth of soil in this orchard. It must be remembered though, that all of the above figures are based on the total roots found in each of the concentric areas sampled, and that the size of these areas increased as the distance from the tree increased. So, although the root content per cubic foot was usually greatest close to the tree trunk a much smaller area was being considered.

The total length of roots in the different areas found in the three different orchards show relatively the same tendencies as the number of roots. It is evident, however, that greater root branching was found in Orchard A at 6 to 9 feet from the tree trunk in the upper

TABLE I—CALCULATED ROOT POPULATION OF 20- TO 25-YEAR-OLD STAYMAN APPLE TREES AT VARIOUS SOIL DEPTHS AND VARYING DISTANCES FROM THE TREE TRUNK

Distance of Sample From Tree Trunk (Feet)	Soil Layer	Number of Roots			Length of Roots (Inches)			Weight of Roots (Gms)			Weight of Fibrous Roots (Gms)		
		Orchard A[1]	Orchard B	Orchard C	Orchard A	Orchard B	Orchard C	Orchard A	Orchard B	Orchard C	Orchard A	Orchard B	Orchard C
0–3	Upper 6 inches	814	584	713	6,481	3,305	4,282	5,226	2,431	12,177	1,058	352	381
	Lower 6 inches	370	753	364	2,806	5,218	2,564	3,053	3,894	2,522	204	587	87
3–6	Upper 6 inches	3,018	1,026	3,139	19,304	9,835	12,552	7,747	6,123	21,718	2,185	782	1,063
	Lower 6 inches	714	1,623	2,187	4,708	12,407	9.530	2,951	7,697	7,208	469	969	249
6–9	Upper 6 inches	3,747	1,841	1,591	21,968	12,101	11,680	6,478	3,656	3,160	1,426	546	1,428
	Lower 6 inches	838	3,881	1,773	4,672	13,429	9,312	1,317	7,361	6,006	285	812	297
9–12	Upper 6 inches	3,403	1,267	1,311	17,605	7,313	9,568	5,275	2,575	7,226	1,266	568	1,296
	Lower 6 inches	1,596	1,314	1,811	4,525	10,087	10,320	577	2,799	6,342	184	633	504

[1]Orchard A—Messick Orchard—soil light sandy loam; permanent weed sod (seven trees sampled).
Orchard B—Harrison Orchard—soil medium sandy clay loam; shallow spring plowing and weed cover crop (six trees sampled).
Orchard C—Caspar Orchard—soil heavy; limestone shale mixed with clay loam; Alfalfa sod (two trees sampled).

layer of soil. The rapid replacement of roots in this area is indicated clearly by the length of roots formed in Orchard B where root pruning by plowing to a depth of 4 inches each year must have cut off much of the root system in the upper 6 inches of soil. However, in this orchard 12,101 inches of roots were found in the upper region compared with 13,429 inches found in the lower 6-inch region. The great length of roots found in the 9- to 12-foot area in Orchard A indicates that in this orchard greater distances from the tree trunk should have been measured to give a complete picture of the root systems of these trees.

As might be expected the weight of individual root was greater close to the tree trunk. Where sod culture had been adhered to this tendency was most emphasized. In Orchard B, where plowing close to the tree trunk pruned off each year a great number of roots, the weight of individual root was less, and somewhat heavier roots were found in the second 6-inch depth than in the first 6-inch layer.

The weight of fibrous roots found in Orchard A and C was tremendously greater in the upper than in the lower 6 inches of soil at all of the distances from the tree trunk. The maximum fibrous roots were found at 3 to 6 feet in Orchard A and at 6 to 9 feet in Orchard B.

The evidence, comparing Orchards A and C with Orchard B further emphasizes the fact that under sod culture development of very fine roots is close to the surface of the ground, where better soil aeration is encountered. The growth of many fine roots in the second 6 inches of soil under clean cultivation, as found in Orchard B, was very marked. At all distances from the tree trunk measured, the greater fibrous root content was always in the lower 6-inch layer of soil. These differences were not as great as in the reverse situation in Orchards A and C, however. Fibrous root population was fairly uniform throughout the surface foot of soil in Orchard B.

Summary and Conclusions

The data presented show that in the upper foot of the soil much root development of mature Stayman apple trees extends outward from the tree trunk up to 12 feet, the greatest distance sampled in this study. The total growth of fibrous roots per foot width of concentric area about the tree apparently reached a maximum at about 6 feet from the tree trunk under the lighter soils which were studied, but in the heavier soil the maximum total fibrous root development was found at 9 to 12 feet with some indication that many fibrous roots might be expected beyond this point. The maximum concentration of fibrous roots per cubic foot of soil was found in all cases within 6 feet of the trunk. The effect of cultivation to a depth of 4 inches is to produce greater root populations in the second 6 inches of soil. Under sod management methods root growth was very much greater in the surface 6 inches of soil than in the second 6-inch layer, over 70 per cent more roots being found in the former than the latter depth.

Acknowledgments

Grateful acknowledgments are extended to Dr. E. C. Auchter who initiated this study and to Dr. A. L. Schrader for corrections in the manuscript.

The Performance of Fruit Tree Seedlings When Dug at Various Stages of Maturity

By F. E. Gardner and G. E. Yerkes, *U. S. Department of Agriculture, Washington, D. C.*

THE objectives of the experiments which are described in this paper were: (a) To determine the effect of digging fruit tree seedlings at various stages of maturity on their subsequent behavior when lined out the following spring for use as stocks, and (b) if the degree of maturity is a factor, to find and describe simple plant criteria which can be used in the field to determine whether or not the seedlings are sufficiently mature for digging.

The experiments are motivated by the fact that occasionally fruit tree stocks, particularly mazzard and mahaleb cherry, fail to grow after being planted out for budding. The tendency of fruit tree seedlings to continue growth late in the fall, on the one hand, and the desire of the seedling grower to harvest his crop as early as possible, on the other, suggested that possibly a lack of sufficient maturity of the seedlings when dug may, among other factors, play an important part in the poor stands which are occasionally experienced. Early fall digging by the seedling grower is prompted by the desire to get his crops out of the ground prior to the advent of fall rains which would make the operation impractical. The time required for other operations such as "sweating off" the leaves, grading and marketing are additional incentives for early digging. It is disclosed in the following experiments that digging before a certain degree of maturity is attained is decidedly detrimental to the future performance of the seedlings.

In the fall of 1930, seedlings of mazzard and mahaleb cherry, Myrobalan plum, Bartlett pear, *Pyrus calleryana*, and French crab apple were dug at various intervals from the nursery at Arlington Farm. For this work areas representative as to stand and size in the seedling planting of each type were first selected. Similar to common nursery practice, the seedlings, upon being dug, were tied in rough bundles and covered with soil in the field in order to "sweat off" the leaves. Later, all seedlings were heeled in over winter in the nursery. Prior to lining out in the spring of 1931, each individual seedling of each digging was weighed and labeled. After growing a season in the nursery each tree was dug and again weighed in the fall of 1931 to determine its growth increment. The percentage survival of each digging was also recorded.

At the time of digging careful observations were made and recorded as to the condition of the seedlings as regards those characters which were likely to be associated with maturity or lack of it. Growth activity at the terminals, ease of separation of bark from wood, ease of stripping or shattering of the leaves, and pigmentation of the stem and leaves were emphasized rather than less apparent indices such as amount of stored food reserves. While it is recognized that maturity is fundamentally an internal condition, yet these more obvious external criteria were adopted in order to be of immediate application in the field.

Results.

The observations as to the degree of maturity recorded at the various digging dates are presented below. They should be considered in conjunction with the percentage survival shown in Tables I and II.

TABLE I—Influence of Maturity on Survival of Mazzard Cherry Seedlings

Date of Digging 1930	Condition of Terminals	Number Dug	Percentage Survival, 1931	Average Per cent Survival, 1931
Sept. 22	Growing	46	2.2	10.5
	Formed	59	17.0	
Sept. 29	Growing	50	12.0	33.6
	Formed	84	46.4	
Oct. 6	Growing	29	79.4	74.4
	Formed	78	73.1	
Oct. 13	Formed but soft	33	48.5	78.7
	Formed	64	90.7	
Oct. 20	Formed	98	89.8	89.8
Oct. 27	Formed	96	95.8	95.8
Nov. 3	Formed	99	99.0	99.0
Nov. 10	Formed	102	95.1	95.1
Nov. 17	Formed	106	100.0	100.1
Nov. 24	Formed	100	90.0	90.0
March 7, 1931	Formed	100	97.0	97.0

Mazzard Cherry, September 22:—Leaves all green and do not separate from the stem without tearing of bark. Bark slips easily from the wood. Approximately one-half of seedlings have formed terminal buds, others still elongating. (Since those still elongating were obviously less mature than those with terminal buds formed, this digging, as well as several immediately following, were correspondingly divided into two lots and kept segregated.)

September 29:—Somewhat fewer number still elongating. (See Table I.) Those still growing terminally are forming shorter internodes. Bark still slips easily on these. On those with terminal buds formed, the bark is tight on upper regions of the stem; still slipping near the ground line.

October 6:—Lower leaves have abscission layers formed; strip easily. Estimate about 25 per cent of seedlings still without terminal buds. Bark slips on lower portion of stem; tight on upper portions. Temperature cool this past week; 38 degrees F last night.

October 13:—Elongation stopped on all plants; with some, the terminals are still very soft. (These were segregated.) Bark tight on all portions of stem except a few with soft terminals; on these the bark still slips near the ground. Leaves falling from lower third of stem of those with more mature terminal buds.

October 20:—Very noticeable change since last week. Bark is tight except on a few which still separate near the ground line. Terminals mostly mature. Leaves falling from lower portions of stem;

upper leaves still green. (Table I disclosed that the plants from this digging gave a fair stand the following spring, but not as good as those dug later.)

October 27:—All terminal buds formed. Bark is tight on practically all plants. Leaves fallen on lower half of stems. Upper leaves beginning to turn brownish, and strip easily.

The percentage survival in the following year of those mazzard seedlings dug on October 27 would indicate that a safe degree of maturity had been attained by this date. The criteria of maturity of the seedlings in the field at this stage are relatively easy to recognize. For want of space, the observations at later diggings are omitted. Although progressive changes had taken place at these later diggings it was not until the middle of November that most of the leaves were dead and fallen.

The importance of leaf area for proper maturation of mazzard cherry seedlings is brought out in the following experiment. On September 15 some of the seedlings were defoliated by hand but allowed to remain otherwise undisturbed until dug November 3. At this time, as Table I shows, a digging of normal seedlings was also made. Those defoliated September 15, however, resulted in a stand the following year of only 21 per cent as compared to nearly a perfect stand from seedlings with normal foliage. Leaf spot, which is a very common and serious nursery disease with mazzard cherry, can quickly and thoroughly defoliate the seedlings so that they may result in a poor stand the following season.

Mahaleb cherry:—Probably no fruit tree stock is more subject to failure when lined out than mahaleb cherry. This is understandable in the light of its habit of growing in full leaf until late in the fall, thereby being more often subject to injury from immature digging. In the observations which follow, only alternate diggings are here recorded.

September 22:—In full leaf and active growth. Bark strips easily. The less vigorous branches on individual plants have stopped elongating. (See Table II for the percentage of terminals still elongating on this and later dates.)

October 6:—Leaves still green, although a few have fallen from lowest portion of the plants. More than half of all terminals have

TABLE II—INFLUENCE OF MATURITY ON SURVIVAL OF MAHALEB CHERRY SEEDLINGS

Date of Digging 1930	Number Dug	Per cent Terminals Still Growing	Per cent Survival 1931
Sept. 22	57	54.8*	5.3
Sept. 29	84	36.4	14.7
Oct. 6	94	32.4	26.6
Oct. 13	83	17.9	14.7
Oct. 20	101	Practically none	51.5
Oct. 27	103	None	58.2
Nov. 3	99	None	81.8
Nov. 10	99	None	89.6
Nov. 17	97	None	99.0
Nov. 24	74	None	89.2

*Individual plants have an average of 10 terminals. Percentage is for all terminals of all plants.

ceased to elongate. Bark slips on lower half of shoots; tight on upper portions.

October 20:—Green color of stems becoming brownish except near tips. Practically all terminal buds formed. Bark is tight on all portions of the stems. Leaves still holding well.

November 3:—Bark becoming grayish on lower portions of plants. Brownish tinge extended to tips. Leaves from the lower half of longer shoots can be stripped off by grasping the stem firmly and sliding the hand upward. Leaves on upper half holding tightly. (This was the earliest digging from which a fairly good stand was obtained—2 weeks later than was the case with mazzard cherry.)

November 17:—Leaves can now be stripped to within five or six buds from tops of longer shoots by sliding the hand upward. Grayish color of bark predominates over whole of stem.

Sufficient maturity of mahaleb cherry seedlings, as indicated by the percentage survival in Table II was attained on November 17. It should be remembered, however, that the condition of the plants rather than the calendar should be the guide for digging.

As stated earlier in the report, loss upon planting out in the nursery is more frequently encountered with mazzard and mahaleb cherry stocks than with any of the other fruit tree seedlings. It is likewise true that in our work the other fruit tree seedlings, apple, pear, and plum, did not suffer so markedly from early digging. In the case of these stocks only one description from the series of observations at different digging dates is recorded here,—that description being the condition of the plants at the time when, as judged by the survival the following season, digging can safely be done.

Bartlett seedlings, October 13:—Not all plants had ceased terminal elongation, about 25 per cent being still without terminal buds. Bark tight on these with terminal buds; still slipped on others. Leaves near the ground were falling; stripped easily from lower half; still held tightly on upper portions. Lower leaves reddish-brown in color; upper leaves still green.

Seedlings dug at this date, October 13, resulted the following year in a 96 per cent stand, whereas of those dug 2 weeks earlier, September 29, only 75 per cent survived.

Pyrus calleryana, October 27:—Terminal shoots have stopped elongating and bark was tight. (Two weeks earlier most terminals were still growing and bark was slipping.) Leaves still holding, except a few near the ground; beginning to change from green to reddish-brown.

Seedlings dug on this date resulted in a 96 per cent stand, while those dug 2 weeks earlier resulted in a 65 per cent stand.

French crab, October 13:—General appearance was that of immaturity. Leaves were green and all holding firmly. Approximately 50 per cent of the seedlings had stopped elongating and bark was tight; balance were still growing slowly and on these the bark still separated. (Two weeks earlier only 20 per cent had formed terminals.)

Differences in the survival percentage of the French crab seedlings dug at the several stages of maturity were not consistent. Al-

though some trend in favor of the more mature seedlings was seen, the evidence from these experiments indicates that French crab is much less affected by its condition when dug than is the case with the other fruit tree stocks.

Myrobalan, November 3:—Leaves still green and holding except near the ground, but could be stripped to within 4 to 12 leaves of the tips. All terminals had ceased to elongate. Bark was tight. (Two weeks earlier approximately 10 per cent of the terminals were still growing and the bark would separate near the ground line.)

The above experiments, started in 1930, were repeated in 1931 with mazzard, mahaleb, Bartlett and French crab. It was found that the descriptions of maturity in each year, for the diggings which resulted in a reasonable percentage of survival, agreed very closely. It should be emphasized, however, that the descriptions of sufficient maturity given here represent the border line and that while loss in the nursery will result if the seedlings are dug in a less mature condition, yet safety lies in delaying this operation as long past this stage as is feasible.

In addition to a successively higher percentage survival, which was found to be the case up to the stage designated as "sufficiently mature", it was not unreasonable to assume that perhaps the more mature seedlings would also make a stronger growth in their second year than those less mature. The seedlings were individually weighed before they were lined out and again at the end of their season in the nursery in order to study this point. Although there appeared to be some indication that greater maturity resulted in greater growth yet the data on this point were far from conclusive and are not included here.

In conclusion, it should be pointed out that while immaturity is no doubt an important factor and one which may be responsible for failure of seedlings to grow, especially in the case of mahaleb cherry, yet it is not the only adverse factor to be guarded against. Improper treatment or conditions during storage and transit may also result in poor stands, particularly if the seedlings are low in vitality as the result of immature digging.

Root Formation in Softwood Cuttings of Apple[1]

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THE rooting of softwood cuttings of apple has presented great difficulties to all who have attempted this means of vegetative propagation. Tukey and Brase (4) experimented with 1,080 cuttings of Northern Spy and French Crab but did not get a single cutting to root. The present authors conducted similar trials with softwood cuttings during the summer of 1931. Two varieties were used, Sharon and Missouri Flat, the latter being a variety which is very easily propagated by layers and suckers. A total of 660 cuttings were made and were tried under a variety of rooting conditions and media. Not one cutting was rooted, although callus formation was very abundant and the cuttings remained in a healthy condition for a very long time. Numerous other experiments, which are summarized by Auchter (1), have generally yielded similar results.

Gardner (2, 3) found that softwood cuttings made from apple seedlings during the first season of growth from seed could be rooted easily. He also found that if the growth of the 1-year cutting was cut back to the ground and cuttings were made from the new shoots produced that considerable rooting could be obtained with these also. The same held true with many other woody plants, cuttings of which normally root with difficulty or not at all.

The work reported in this paper shows that, in the apple, wood capable of rooting is not limited to growth on the juvenile seedling form, but may under certain conditions be produced in older trees on shoots arising from adventitious buds.

In one experiment, root cuttings about 6 inches long were made from open-pollinated apple seedlings in which the seed parents were known. On May 25, 1934, the cuttings were planted in a sandy soil in a cool greenhouse. The seedling trees from which the cuttings were made were started from seeds in the spring of 1930 and thus had gone through four seasons in the nursery. Sprouts soon arose from the adventitious buds formed on the roots and when they reached the height of about 1 foot, softwood cuttings were made from these. One precaution which was taken in all experiments was to obtain the cuttings always from the tips of the shoots and at least several inches above the ground line in order to eliminate any effect of etiolation.

The cuttings which were made on June 30 and July 13 were inserted in tight outdoor frames with muslin shade, the type generally used by nurserymen for summer propagation. Washed sand was used as the rooting medium. A gentle bottom heat was provided by a layer of decomposing manure. The temperature of the rooting medium fluctuated somewhat but generally ranged from 65 to 75 degrees F. The conditions in closed frames are particularly favorable to the development of certain fungous diseases which are destructive to apple cut-

[1]Journal Paper No. J208 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 291.

tings; consequently careful attention must be given to the regulation of the heat and humidity.

Rooting took place in 3 to 6 weeks after the cuttings were inserted. The results of this experiment are shown in Table I, together with some data secured with cuttings taken at later dates. The cuttings made on September 13 and 21 were handled in the same manner as those made in midsummer, except that they were placed in a closed propagating frame in a greenhouse.

TABLE I—ROOTING OF SOFTWOOD CUTTINGS MADE FROM APPLE SHOOTS ON ROOT CUTTINGS

Date Cuttings Taken	Seed Parent of Experimental Trees	Number of Cuttings	Number of Cuttings Rooted
June 30	Wealthy x Ben Davis	25	2
June 30	Briar Sweet x Mercer County	25	17
June 30	McIntosh	25	8
June 30	Anisim (self pollinated)	25	8
July 13	Anisim (self pollinated)	25	8
July 13	Tolman Sweet	25	2
July 13	Briar Sweet x Mercer County	25	2
July 13	Northern Spy x Patten Greening	25	3
Sept. 13	Wealthy x Ben Davis	50	6
Sept. 13	*Malus Niedzwetzkyana*	50	24
Sept. 21	French Crab	25	2
Sept. 21	Tolman Sweet	25	4
Sept. 21	McIntosh	25	4
Sept. 21	Grimes Golden	25	7

It will be noticed from Table I that rooting can be obtained in shoots grown from seedlings older than 1 or 2 years. Although the trees used had very wide differences in genetic constitution, some rooting was obtained in every lot of cuttings. The small number of cuttings rooting in several lots in all probability was due to attacks of damping off fungi in the propagating frame.

Juvenile seedling shoots of apple have some external morphological differences from those which are produced from ordinary nodal buds on orchard trees. On a seedling shoot such as those used in the experiments of Gardner the leaves are very thin and smooth, while those on a sprout of the same size and age on an orchard tree will have considerable pubescence. Sprouts arising from the crown roots of orchard trees or from plants recently started from root cuttings resemble the juvenile seedling shoot in appearance.

Another trial of rooting was made with softwood cuttings taken from adventitious sprouts which arose from the crowns of 14-year-old seedling trees. All of these possessed this external similarity to the juvenile seedling form. As sucker growth of this sort is held down by cultural practices, it was not abundant and no attempt was made to keep the cuttings from different trees separate. In one lot of 25 cuttings made on May 17 from this type of material, 17 rooted. Several of these cuttings are shown in Fig. 1.

Material was available for cuttings from adventitious sprouts of one standard variety. In one of the orchards a group of trees of the

FIG. 1. Root formation in cuttings made from sprouts taken from crown roots of 14-year-old trees.

variety Virginia Crab, root grafted on French Crab stocks, had been planted in 1917. Cion rooting had taken place on these trees. After the trees were pulled out in 1929 numerous sprouts arose from the cion roots which were left in the ground. Unfortunately many of the shoots were tall and very woody, but some were quite young and succulent. Softwood cuttings were made from these. From a lot of

FIG. 2. Virginia Crab variety. Pot grown, softwood cuttings made from adventitious sprouts from own-rooted trees.

25 cuttings made on May 14, 14 cuttings rooted. Several rooted cuttings of Virginia Crab growing in pots are shown in Fig. 2. Doubtless the rooting secured from the cuttings made from adventitious sprouts under the conditions of the above experiments was due to some anatomical or biochemical characteristics which they possessed in common with the juvenile seedling shoots.

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Dormant Rose Plants as Affected by Temperature and Moisture While in Storage

By G. E. YERKES and F. E. GARDNER, *U. S. Department of Agriculture, Washington, D. C.*

THE object of the following storage experiments with dormant field-grown roses was to determine the relative effectiveness of different percentages of moisture in the packing material surrounding the plants as well as that of different temperatures, in maintaining the plants in good condition during the storage period. The published information on these factors in their practical application to roses in storage is meager, although the rose is one of the most important of nursery products with an annual crop of at least 20 million plants. Storage of rose plants offers more risk of loss than is the case with most deciduous trees and shrubs. Roses will break dormancy more readily than many other kinds of woody plants if kept moist, and, on the other hand, they quickly suffer from desiccation if exposed to dry air. Another form of deterioration is break down and mold of tissue, commonly referred to as "dieback." Autumn transplanting is often advised, which, if more generally practiced where conditions permit, would be an advantage to both the nurseryman and the grower, by avoiding the intervention of a period in storage. Yet, under the present conditions of handling and distribution, the bulk of dormant roses must be preserved out of the ground over winter.

Three experiments were carried through winter and spring storage periods, all with plants packed in ordinary nursery boxes lined with kraft paper and double lined with oiled paper to reduce loss of moisture as much as practicable. Both granulated peat and shingletow were used for packing materials. Two methods of packing were employed; one in which only the roots were covered, the other in which both canes and roots were completely packed.

In one test, 10 plants each of Charles K. Douglas, Luxembourg, Los Angeles, Sunburst, Kaiserin Augusta Viktoria, Mrs. Charles Bell, and *Rosa multiflora* were used in each treatment. The various lots of packing material were prepared with known proportions of water, namely 40, 48, 58, and 65 per cent, by weight of the moist packing, respectively. These percentages were chosen in order to have some moisture conditions lower and others higher than the moisture content of the plants themselves which was found to be near 48 per cent. The storage period was of 60 days duration and three different temperature conditions were employed, namely; common storage with a variable mean temperature of 48 degrees F and controlled storage at 40 and 50 degrees. These comparatively high temperatures were chosen in order that the various moisture conditions might demonstrate more readily their relative influence in maintaining the stored plants in a fresh condition with a minimum of sprouting.

In a second experiment, involving 15 varieties, a winter storage period of 93 days was used. Both common storage and controlled cold storage were employed. In common storage with a mean temperature of 44 degrees F the moisture content of the various lots was 36, 42,

48, and 65 per cent, respectively. In cold storage at constant temperatures of 30 and 36 degrees F, only two moisture percentages, namely, 42 and 58 per cent, were adopted.

Another experiment was designed to determine the effectiveness of relatively low temperatures in maintaining dormancy for delayed spring planting of both hybrid teas and climbers. In this experiment the moisture of the packing material was uniform in all lots. The plants, 210 in each treatment, were tightly packed in boxes and placed at constant temperatures of 30, 32, 36, and 40 degrees F respectively, from March 4 to May 25. When removed from storage the plants were promptly lined out in the nursery. At this time a comparable check lot which had been planted in the nursery on March 4, instead of being stored with the others, was already in full bloom.

The results which follow are discussed collectively as responses to temperature and moisture rather than adhering strictly to individual experiments.

Condition of plants from cold storage:—From the 30-degree F storage, in each test all the plants came out in practically the same condition as when put in. No decayed canes were found, and only traces of mold. At this temperature the packing remained in a frozen state but 30 degrees was not cold enough to freeze the plants themselves. Both the plants in the wet (58 per cent) and dry (42 per cent) packs remained completely dormant. In all respects, a storage temperature of 30 degrees gave better results than any treatment in our experiments. At 32 degrees a tendency to break dormancy was evident and the influence of differential moisture could be seen in that the plants from the packing with 42 per cent moisture remained practically dormant while those from 58 per cent were slightly sprouted. At 36 degrees plants from both the wet and dry packs had begun to start both from branch buds and root points, but this new growth had not advanced as far in the 42 per cent pack as in the 58 per cent pack.

In the experiment for delayed spring planting in which various low temperatures were employed but the moisture factor remained uniform, the following observations as to the degree of dormancy of the plants was made after 82 days of storage; at 32 degrees F the mean elongation of the longest shoot in each variety was .7 inch; at 36 degrees, elongation had increased to 2 inches; while at 40 degrees it was 3.5 inches. Measurements of the longest shoot were taken as the best expression of growth, although buds on the same plants varied through all stages of development up to the length recorded. At 36 and 40 degrees, mold and dieback made some pruning necessary when the plants were taken out, which detracted from the appearance of the plants, but ample sound wood remained to insure successful planting.

After planting in the nursery few plants were lost and but little difference in percentage survival was evident between lots, although there was a noticeable difference in growth during the following several weeks of rather hot weather. The plants from 30 and 32 degrees F established themselves sooner, and the hybrid teas blossomed 7 to 9 days earlier than those from 40 degrees. By autumn, however, these differences in growth were not so noticeable. The survival of plants was as follows:

Transplanted March 4 (check lot not stored) 99.5 per cent.

Transplanted May 26 after storage at 30 degrees, 99.3 per cent; at 32 degrees, 100 per cent; at 36 degrees, 98.5 per cent; and at 40 degrees, 92 per cent.

The practical value of cold storage at 30 degrees F is indicated by these tests to be applicable for prolonging the season for transplanting roses until very late in spring as well as for the usual period of winter storage now utilized commercially to a limited extent.

Influence of moisture in the packing in common storage:—In an ordinary nursery cellar with a mean temperature of 44 degrees F during winter and 48 degrees in early spring, the amount of moisture present in the peat or shingletow packing had an important influence on growth during storage. The plants in the dryest pack of 36 per cent moisture grew least in storage and remained in better condition than any of the other treatments although this packing contained a much smaller percentage of water than the plants themselves had originally. The wood gave but little indication of injury by drying, such drying as did occur being limited to a few canes in the corners of some of the boxes. It should be borne in mind, however, that the plants were boxed in a manner to minimize loss of moisture by evaporation. If stored in bulk with only the roots covered, as in general practice, a packing as dry as 36 per cent moisture would probably result in shrivelling of the canes within a short time even in a fairly humid atmosphere.

With higher percentages of moisture in the packing material, growth elongation increased progressively, as illustrated in Fig 1. When taken out of common storage the longest new growth on plants surrounded by packing with 36 per cent moisture averaged 1.5 inches, while with those in 65 per cent moisture the new growth had elongated to 6.3 inches. Similar responses to moisture differences in the packing were obtained in all the tests where the temperature was above freezing.

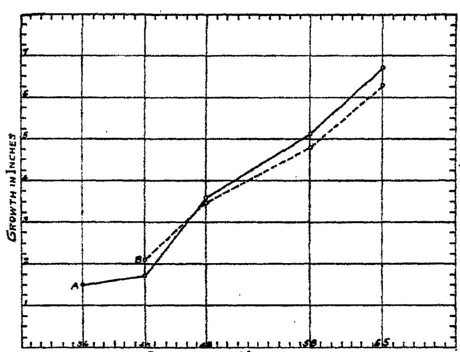

FIG. 1. Growth elongation of rose plants packed in material with different moisture percentages, after 97 days at 44 degrees F mean temperature in common storage. (A) Space all filled with packing material; (B) Space around canes open, roots tightly packed.

The manner of packing had little effect on growth in storage. The boxes with all the space filled with peat or shingletow around the canes as well as the roots, preserved the plants in practically the same state as those with only the roots covered. The differences in growth elongation between these two methods of covering were too narrow to be significant. However, drying out of the canes would be reduced by

covering the tops as well as the roots when the plants are stored in open bulk. On the other hand, this procedure, if adopted with very wet packing material, would result in excessive sprouting and subsequent rotting of the sprouts as well as the canes.

These results indicate rather clearly that even in unavoidably warm common storage temperatures with a mean near 45 degrees F, roses can be kept in fairly good condition, though not fully dormant, by preparing the packing material with a moisture content of 36 to 40 per cent. This treatment cannot be expected to give as good results as storage at a constant low temperature just below freezing, but its advantages can be had without materially increasing the cost.

Dieback of wood while in storage:—Damage from decay in the canes was found in plants from all treatments except those kept at 30 and 32 degrees F. Usually the breakdown began at the tips and in the softer wood and spread toward the main axis of the plant. In most cases enough healthy wood remained after pruning off the affected branches to save the plants although their appearance was marred and their sale value thus adversely affected.

The amount of injury from dieback varied so much among the several treatments that no significant trend was discovered which could be ascribed to the water content in the packing material. The condition of the wood with respect to its maturity was an important factor, the damage being greatest in the canes of recent growth. This suggests that the quality of rose plants which are to be stored might be improved by cultural treatment which would provide for ripening the growth as much as possible before digging. In the preparation of the plants for storage all soft growth should be pruned off.

Rather consistent varietal differences in the amount of injury from dieback were apparent in these experiments. Of the varieties used, Luxembourg, Los Angeles, and Sunburst showed greatest injury, whereas Rapture and Talisman of the hybrid tea varieties showed least injury. Radiance, Mrs. Charles Bell, and C. K. Douglas all lost a rather large percentage of wood when stored at the higher temperatures. However, in the case of these more vigorous varieties ample sound wood remained for successful planting.

Summary

The storage temperature which maintained boxed lots of rose plants in best condition was 30 degrees F. In common storage, with a mean temperature of 44 to 48 degrees F, the growth of plants in storage increased progressively with the water content of the packing material. This correlation was found in all temperatures above freezing. Packing material prepared with moisture contents of 36 per cent and 40 per cent maintained the plants in common storage in better condition than packing with higher moisture contents. Damage from decay while in storage varied more with the condition of the plants as regards maturity, and also with the variety than with the water content of the packing material.

An Analysis of the Breeding Value of Certain Plum Varieties[1]

By W. H. Alderman and Ernest Angelo, *University of Minnesota, St. Paul, Minn.*

At the University of Minnesota Fruit Breeding Farm the development of hardy varieties of plums has been continuously under way since 1908. The most important developments of this enterprise have come from hybridization of Asiatic and American species. The early work consisted largely of inter specific crosses of varieties of *Prunus salicina* with those of *P. americana* and *P. nigra*. Other crosses were made between the American species and a number of hybrids produced by such breeders as Theodore Williams of Benson, Nebraska, Dr. N. E. Hansen of the South Dakota Experiment Station, and Luther Burbank. Because of the heterozygous condition of the parents, these lines of breeding were producing widely variable populations of seedlings from which valuable selections were made. It was thought possible, however, that the pure species used as parents might not be sufficiently heterozygous with respect to the genes determining the species characters to allow the occurrence of complete segregation in the first generation. Consequently a second generation was obtained by means of sib matings and other crosses of first generation seedlings. The original program of making inter specific crosses and the growing of some open pollinated seed was also continued.

In the last 12 years there have been fruited 2980 of these seedlings representing 85 different parental combinations. These are survivors after an undetermined amount of natural selection for hardiness has taken place. In Table I is given a detailed record of each combination and the number of *fair, good,* and *superior* seedlings which have been selected as worthy of further trial. Insofar as they are known to the writers the species or varieties from which the parents were derived are also given in Table I. It is hoped that this extended tabulation will be of some value to fruit breeders in selecting promising parents for further work. The arbitrary ratings given selected seedlings and parents are not based upon quality alone but upon all those characteristics which are normally considered in determining the value of a variety of fruit. From the total of 2980 seedlings, 138 were selected representing 41 combinations. It should be noted, however, that only 31 seedlings are given *superior* rating and these were derived from 14 combinations. Of these 31 superior seedlings, 23 had Burbank for one parent, and of these 10 appeared in a Burbank x Kaga cross. All but three of the superior seedlings came from combinations in which one or both of the parents was given a *superior* rating. No statistical significance is attached to this point, however, since these groups had larger populations than the others. As a matter of fact *superior* x *fair* parents produced a much greater proportion of outstanding seedlings than did *superior* x *good* parents. It does indicate, however, that *superiority* in at least one parent is very important.

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TABLE I—RECORD OF SEEDLINGS PRODUCED BY VARIOUS CROSSES.
In Parent Ratings F = Fair, G = Good, S = Superior

Cross	Rating of Parents		Number Seedlings Grown	Number Seedlings Selected	Rating of Selected Seedlings		
	Female	Male			Fair	Good	Superior
Assiniboin (*P. nigra*) x Surprise (*P. hortulana mineri*)	G.	G.	106	0	0	0	0
Burbank (*P. salicina*) x Assiniboin (*P. nigra*)........	S.	G.	13	0	0	0	0
Burbank (*P. salicina*) x Kaga (*P. americana* x *P. simoni*)	S.	S.	267	32	2	20	10
Burbank (*P. salicina*) x Mendota (Burbank x Wolf)	S.	S.	5	1	1	0	0
Burbank (*P. salicina*) x *P. simoni*..................	S.	S.	8	2	2	0	0
Burbank (*P. salicina*) x Stella (Unknown)............	S.	F.	6	1	0	1	0
Burbank (*P. salicina*) x Surprise (*P. hortulana mineri*)	S.	G.	11	1	0	0	1
Burbank (*P. salicina*) x Winnipeg (*P. nigra*)......	S.	F.	12	1	1	0	0
Burbank (*P. salicina*) x Wolf (*P. americana*)......	S.	F.	28	7	0	5	2
Elliott (*P. salicina* x *P. americana*) x Mendota (Burbank x Wolf)........	S.	S.	36	0	0	0	0
Kaga (*P. americana* x *P. simoni*) x Burbank (*P. salicina*)................	S.	S.	20	0	0	0	0
Mendota (Burbank x Wolf) x Kaga (*P. americana* x *P. simoni*)..............	S.	S.	10	2	0	2	0
Mound (Burbank x Wolf) x Mendota (Burbank x Wolf)..................	S.	S.	12	0	0	0	0
October (*P. salicina*) x Assiniboin (*P. nigra*)........	G.	G.	9	2	0	2	0
Opata (*P. besseyi* x Gold) x Wickson (*P. salicina* x *P. simoni*..............	F.	S.	14	1	1	0	0
Red Wing (Burbank x Wolf) x Assiniboin (*P. nigra*)....	S.	G.	174	0	0	0	0
Red Wing (Burbank x Wolf) x Kaga (*P. americana* x *P. simoni*)..............	S.	S.	82	2	0	2	0
Red Wing (Burbank x Wolf) x Mendota (Burbank x Wolf)..................	S.	S.	26	0	0	0	0
Red Wing (Burbank x Wolf) x Terry (*P. americana*)...	S.	G.	12	0	0	0	0
Sapa (*P. besseyi* x Sultan) x Kaga (*P. americana* x *P. simoni*)................	S.	S.	14	0	0	0	0
Sapa (*P. besseyi* x Sultan) x Mendota (Burbank x Wolf)..................	S.	S.	19	0	0	0	0
Sapa (*P. besseyi* x Sultan) x Surprise (*P. hortulana mineri*)..................	S.	G.	24	0	0	0	0
Shiro (Complex hybrid) x Wyant (*P. americana*)....	S.	F.	2	1	0	0	1
Surprise (*P. hortulana mineri*) x Assiniboin (*P. nigra*)................	G.	G.	94	0	0	0	0
Surprise (*P. hortulana mineri*) x Terry (*P. americana*)	G.	G.	17	3	1	1	1
Terry (*P. americana*) x Wolf (*P. americana*)......	G.	F.	13	0	0	0	0
Tonka (Burbank x Wolf) x Kaga (*P. americana* x *P. simoni*)...............	S.	S.	4	1	1	0	0
Tonka (Burbank x Wolf) x Terry (*P. americana*).....	S.	G.	17	0	0	0	0
Tonka (Burbank x Wolf) x Red Wing (Burbank x Wolf)..................	S.	S.	32	0	0	0	0
Underwood (Shiro x Wyant) x Red Wing (Burbank x Wolf)..................	S.	S.	6	2	0	2	0

TABLE I—*Continued*

Cross	Rating Parents		Number Seed-lings Grown	Number Seed-lings Selected	Rating of Selected Seedlings		
	Fe-male	Male			Fair	Good	Superior
Waconia (Burbank x Wolf) x Kaga (*P. americana* x *P. simoni*)	F.	S.	11	0	0	0	0
Wakapa (Red June x De-Soto) x Burbank (*P. salicina*)	G.	S.	17	0	0	0	0
Wolf (*P. americana*) x Burbank (*P. salicina*)	F.	S.	14	1	0	1	0
Zumbra (Complex hybrid) x Hennepin (Satsuma x *P. americana*)	G.	F.	6	1	0	0	1
Assiniboin (*P. nigra*) x New Hampshire No. 5 (*P. salicina*)	G.	F.	10	0	0	0	0
Burbank (*P. salicina*) x New Hampshire No. 5 (*P. salicina*)	S.	F.	15	0	0	0	0
Burbank (*P. salicina*) x *P. americana*	S.	F.	196	18	3	8	7
Burbank (*P. salicina*) x *P. besseyi*	S.	F.	52	2	2	0	0
Burbank (*P. salicina*) x Minn. No. 2 (Burbank x Wolf)	S.	F.	17	0	0	0	0
Burbank (*P. salicina*) x Minn. No. 35 (Abundance x Wolf)	S.	S.	134	5	1	3	1
Burbank (*P. salicina*) x Minn., No. 98 (Unknown)	S.	F.	9	1	0	0	1
October (*P. salicina*) x *P. americana*	G.	F.	.13	1	0	0	1
Red Wing (Burbank x Wolf) x Minn. No. 35 (Abundance x Wolf)	S.	S.	17	1	1	0	0
Surprise (*P. hortulana mineri*) x Minn. No. 57 (Shiro x Winnipeg)	G.	F.	13	0	0	0	0
Tonka (Burbank x Wolf) x S. Dak. No. 27 (Unknown)	S.	G.	20	0	0	0	0
Underwood (Shiro x Wyant) x Minn. No. 83 (Shiro x S. Dak. No. 33)	S.	S.	11	0	0	0	0
Winona (Abundance x Wolf) x Minn. No. 98 (Unknown)	S.	F.	24	2	1	1	0
Winona (Abundance x Wolf) x S. Dak. No. 27 (Unknown)	S.	G.	16	0	0	0	0
Older No. 1 (Unknown) x Shiro (Complex hybrid)	G.	S.	8	1	0	1	0
P. americana x Burbank (*P. salicina*)	F.	S.	50	1	0	1	0
S. Dak. No. 27 (Unknown) x Burbank (*P. salicina*)	G.	S.	56	2	0	1	1
S. Dak. No. 27 (Unknown) x Mound (Burbank x Wolf)	G.	S.	11	1	0	1	0
S. Dak. No. 27 (Unknown) x October (*P. salicina*)	G.	G.	23	0	0	0	0
S. Dak. No. 27 (Unknown) x Santa Rosa (*P. salicina*)	G.	S.	91	7	0	5	2
Minn. No. 6 (Burbank x Wolf) x Terry (*P. americana*)	G.	G.	21	0	0	0	0
Minn. No. 9 (Burbank x Wolf) x Burbank (*P. salicina*)	F.	S.	5	1	0	1	0
Minn. No. 35 (Abundance x Wolf) x Burbank (*P. salicina*)	S.	S.	10	0	0	0	0
Minn. No. 35 (Abundance x Wolf) x Winona (Abundance x Wolf)	S.	S.	1	1	0	0	1
Minnesota No. 89 (Wasteca x First) x Shiro (Complex hybrid)	G.	S.	8	2	0	2	0
Minnesota No. 9 (Burbank x Wolf) x Minn. No. 2 (Burbank x Wolf)	F.	F.	10	0	0	0	0

TABLE I—*Continued*

Cross	Rating of Parents		Number Seedlings Grown	Number Seedlings Selected	Rating of Selected Seedlings		
	Female	Male			Fair	Good	Superior
Minnesota No. 57 (Shiro x Winnipeg (x Minn. No. 55 (Abundance x Wolf) x (Unknown)............	F.	F.	44	0	0	0	0
Minn. No. 59 (Shiro x Winnipeg) x Minn. No. 57 (Shiro x Winnipeg).......	F.	F.	53	0	0	0	0
Minn. No. 62 (Shiro x Bursota) x Minn. No. 57 (Shiro x Winnipeg).......	F.	F.	57	0	0	0	0
Minn. No. 64 (Shiro x *P. americana*) x Minn. No. 78 (Shiro x *P. americana*)....	G.	G.	17	0	0	0	0
Minn. No. 65 (Shiro x Wolf) x Minn. No. 73 (DeSoto x Shiro)................	G.	S.	13	1	0	1	0
Minn. No. 66 (Shiro x Wolf) x Minn. No. 65 (Shiro x Wolf)................	G.	G.	15	0	0	0	0
Minn. No. 69 (Burbank x *P. americana*) x Minn. No. 98 (Unknown)...........	S.	F.	8	1	0	1	0
Minn. No. 76 (Burbank x *P. americana*) x Minn. No. 62 (Shiro x Bursota)........	G.	G.	20	0	0	0	0
Minn. No. 77 (Shiro x *P. americana*) x Minn. No. 84 (S. Dak. No. 22 x Shiro)	G.	S.	13	0	0	0	0
Minn. No. 83 (Shiro x S. Dak. No. 33) x Minn. No. 60 (Shiro x S. Dak. No. 33)..................	S.	S.	16	1	0	1	0
Minn. No. 83 (Shiro x S. Dak. No. 33) x Minn. No. 66 (Shiro x Wolf)........	S.	F.	2	1	0	0	1
Minn. No. 84 (S. Dak. No. 22 x Shiro) x Minn. No. 77 (Shiro x *P. amerixana*)	S.	G.	44	0	0	0	0
Minn. No. 89 (Wasteca x First) x S. Dak. No. 27 (Unknown)............	G.	G.	23	2	0	2	0
Minn. No. 92 (Omaha x Wyant) x Minn. No. 74 (Complex hybrid)........	F.	F.	84	1	1	0	0
Minn. No. 92 (Omaha x Wyant) x Minn. No. 102 (Burbank x Jewel).......	F.	F.	12	0	0	0	0
Minn. No. 92 (Omaha x Wyant) x Minn. No. 106 (Omaha x Santa Rosa)....	F.	F.	52	0	0	0	0
Minn. No. 106 (Omaha x Santa Rosa) x Minnesota No. 55 (Abundance x Wolf) x (Unknown)......	F.	F.	11	0	0	0	0
Minn. No. 106 (Omaha x Santa Rosa) x Minn. No. 59 (Shiro x Winnipeg)....	F.	F.	11	0	0	0	0
Assiniboin (*P. nigra*) open pollinated..............	G.	?	209	17	16	1	0
Burbank (*P. salicina*) open pollinated..............	S.	?	39	3	0	3	0
Compass (*P. besseyi* x Miner) open pollinated.......	G.	?	37	0	0	0	0
Mendota (Burbank x Wolf) open pollinated..........	S.	?	29	0	0	0	0
Red Wing (Burbank x Wolf) open pollinated..........	S.	?	16	0	0	0	0
Stella (Unknown) open pollinated................	F.	?	70	0	0	0	0
Winipeg (*P. nigra*) open pollinated................	F.	?	103	4	4	0	0
Total................			2980	138	38	69	31

In a previous report Angelo and Alderman (1) pointed out that first generation seedlings from *Prunus americana* and *P. nigra* crossed with *P. salicina* seemed to show as great segregation for species characters as did the second generation seedlings. In Table II is shown a Burbank x Wolf reciprocal cross with small populations in the first generation, second generation (by sib mating), and a back cross to Burbank. In the first generation, 20 per cent of the seedlings were given a good or superior rating. In the back cross, 7 per cent were rated fair or good, while in the second generation, no seedlings were found worthy of even a fair rating.

TABLE II—SEEDLINGS OF RECIPROCAL CROSS OF BURBANK AND WOLF IN FIRST GENERATION, SECOND GENERATION, AND BACK CROSS

	Total Seedlings	Selected Seedlings	Rating of Selections		
			Fair	Good	Superior
First generation seedlings....	42	8	–	6	2
Second generation seedlings..	80	0	–	–	–
Back cross................	27	2	1	1	–

In Table I are listed 54 other seedlings that may be considered second generation populations from crosses of *Prunus salicina* and *P. americana*. Only two individuals were selected from this group, one rating *fair* and the other *superior*. If this group is added to the 80 second generation seedlings of Burbank and Wolf we have a total population of 134 producing only two varieties worthy of further testing, a ratio of 67 to 1. This should be compared with Table III in which are listed first generation seedlings from reciprocal crosses between *P. salicina* and *P. americana* where 301 seedlings yield 28 worthy of selection or a ratio of about 11 to 1. Further evidence of a somewhat similar nature comes from crosses of Shiro, a complex hybrid, with varieties of *P. americana* and *P. nigra*. These crosses which were made prior to the work reported in this paper produced a large number of promising seedlings from rather small populations and indicated that Shiro was an exceptionally good parent. When, however, a number of these selected seedlings were recombined to produce a second generation of 184 individuals only three were selected, a ratio of 61 to 1. It is possible that the complexity of the genetic make up of such parental material necessitates the production of large seedling populations to insure desirable recombinations of superior characters.

Table III summarizes the results obtained from all first generation inter-specific crosses. It is apparent that the hybrids coming from crosses of *Prunus salicina* with various American species are far more productive of good seedlings than are those from crosses between American species. The one cross in the latter group which produced any seedlings rating fair or better combined two native varieties of exceptionally good quality, Surprise and Terry. Varieties of *P. salicina* cross readily with native species and introduce into the combina-

TABLE III—SEEDLINGS FROM FIRST GENERATION INTER-SPECIFIC CROSSES

	Total Seedlings	Selected Seedlings	Rating of Selections		
			Fair	Good	Superior
P. salicina x *P. americana*........	237	26	3	13	10
P. americana x *P. salicina*........	64	2	–	2	—
P. salicina x *P. nigra*............	34	3	1	2	—
P. salicina x *P. besseyi*...........	52	2	2	—	—
P. salicina x *P. hortulana mineri*...	11	1	–	—	1
Total Asiatic-American hybrids ..	398	34	6	17	11
P. hortulana mineri x *P. americana*	17	3	1	1	1
P. hortulana mineri x *P. nigra*.....	94	0	–	—	—
P. nigra x *P. hortulana mineri*.....	106	0	–	—	—
Total American hybrids.........	217	3	1	1	1

tions valuable fruit characters, such as size, firmness of flesh, adherence of stem, and distinctive flavor.

An interesting feature of Table III are the reciprocal crosses of *Prunus salicina* and *P. americana*. Where the Japanese species is used as the female parent the progeny yields a large proportion of seedlings worthy of selection, the ratio being 9 to 1. When the cross is reversed and *P. americana* is the maternal parent the ratio of total to good seedlings is 31 to 1. In such a cross the plant breeder more than trebles his chances of securing good seedlings by using *P. salicina* as the female parent rather than *P. americana*. In a previous paper Angelo and Alderman (1) reported that in such crosses as these the characters of the progeny resembled the maternal to a greater degree than the paternal parent. This so-called "maternal influence" will account for the difference in proportions of good seedlings derived from the reciprocal crosses since the Japanese species carries a preponderance of the more desirable characters.

One object of this paper is to indicate varieties of plums that have proven to be good parents. A study of Table I discloses a number of promising combinations, in most of which the variety Burbank appears. Other valuable varieties are Kaga, Shiro, October, Underwood, Wolf, Wyant, Santa Rosa, and South Dakota No. 27. Especially outstanding are the combinations of Burbank x Kaga and Burbank x Wolf.

The use of open pollinated seed of good varieties is a common practice among fruit breeders and is often productive of satisfactory results. An examination of the last seven items in Table I indicates that the chances of securing valuable seedlings following open pollination are not very good unless large numbers are grown. It should be explained that the large number of selections from Assiniboin and Winnipeg were based upon winter hardiness more than fruit characters. Had these selections been made upon the same basis as others in the table only one would be listed instead of 21.

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The Fertilization of Shade Trees in the Nursery

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PRESENT commercial practices of stimulating growth of shade trees in nurseries and on lawns are based for the most part on results obtained from fertilizer experiments with fruits. This, in general, is a fallacious practice, since the ultimate objectives in the production of shade and fruit trees are distinctly different. This paper is presented as a progress report of shade tree fertilization tests being conducted at Ohio State University and as a plea for more extensive investigations in this field.

In November 1931 a block of 500 Moline elms *(Ulmus americana Moline)* were planted in rows 8 by 10 feet in a well prepared field of silt loam soil. The field was previously in an alfalfa sod and has a slightly eastern exposure. Trees were selected for a uniform height of 7 to 8 feet and a caliper of about 1½ centimeters 2 feet above the graft union. Since the plants selected are grafts they may be considered to be less variable in growth habit than would be a similar number of seedlings.

The block was divided into four sections which received applications of fertilizer in (a) spring, (b) spring and July, (c) July and fall, and (d) fall. Each section was divided into five plots of 25 trees each. Besides the control plots the fertilizers applied to each section were an inorganic 12–6–4, an organic 6–6–4, ammonium sulphate, and a mixture of ammonium sulphate and superphosphate. Applications were made so that each plot received approximately the same quantity of nitrogen at each application. Some discrepancies will be noted in Table I due to changes in formula of the fertilizers used. The applications made in 1932 were the same as 1933 and as indicated in Table I. In 1934 the applications were computed on the basis of adding ¼ pound of nitrogen and ½ pound of superphosphate per inch in diameter of the tree. Since the average caliper of all trees at the end of the 1933 season was approximately 1 inch, this figure was used as a basis for all fertilizer allocations. The fertilizer was spread broadcast in a circle 3 feet in diameter about the trees. Only those plots receiving applications of superphosphate were hoed in. Cultivation was practiced throughout the growing season.

Measurements were made each year in early November. In 1932 and 1933 the data consisted of the average twig growth and the caliper of each tree. Since these two determinations showed comparable results the first 2 years, caliper readings only were taken in 1934. Measurements were taken with a standard calibrated caliper at a permanent mark on each tree approximately 2 feet above the graft union. Since the fall plots had only just received applications of fertilizer when the measurements were made in 1932, the figures for this year are not given in the tables.

A review of the data recorded in the tables shows little consistency in reaction for a single type of fertilizer applied at different periods of the year. This is to be expected since the availability of the elements depends on such factors as moisture and temperature of the soil. Like-

TABLE I—RESPONSE OF MOLINE ELMS (*Ulmus americana moline*) TO FERTILIZER TREATMENTS

Plot	Fertilizer Applied	1933 Amount Applied (Gms)	1933 Time of Application	1933 Av. Diameter of Trunk Per Plot (Cms)	1933 Av. Increase in Caliper per Plot During 1933 (Cms)	1934 Amount Applied (Pounds)	1934 Time of Application	1934 Av. Diameter of Trunk Per Plot (Cms)	1934 Av. Increase in Caliper per Plot During 1934 (Cms)
1	Control	—	—	1.85	.33	—	—	2.54	.69
2	12-6-4	250	Oct. 7	2.03	.46	2.00	Oct. 10	2.80	.77
3	6-6-4	375	Oct. 7	2.27	.57	2.50	Oct. 10	2.83	.56
4	Ammonium sulphate 20%	125	Oct. 7	2.31	.64	1.25	Oct. 10	3.12	.81
5	Ammonium sulphate 20%,	125				1.25			
	Superphosphate 20%	250	Oct. 7	2.78	1.04	3.00	Oct. 10	3.94	1.16
7	12-6-4	250	July 15, Oct. 7	2.47	.61	2.00	July 5, Oct. 10	3.20	.73
8	6-6-4	375	July 15, Oct. 7	2.39	.76	2.50	July 5, Oct. 10	2.94	.55
9	Ammonium sulphate 20%	125	July 15, Oct. 7	2.25	.61	1.25	July 5, Oct. 10	2.76	.51
10	Ammonium sulphate 20%,	125				1.25			
	Superphosphate 20%	250	July 15, Oct. 7	2.50	.77	3.00	Oct. 10	3.18	.68
11	Control	—	—	2.37	.65	—	—	3.06	.69
12	12-6-4	250	June 1	2.52	.68	2.00	May 19	3.34	.82
13	6-6-4	375	June 1	2.41	.66	2.50	May 19	2.77	.36
14	Ammonium sulphate 20%	125	June 1	2.19	.49	1.25	May 19	2.42	.23
15	Ammonium sulphate 20%,	125				1.25			
	Superphosphate 20%	250	June 1	2.35	.68	3.00	May 19	2.80	.45
17	12-6-4	250	June 1, July 15	2.57	.87	2.00	May 19, July 5	3.33	.76
18	6-6-4	375	June 1, July 15	2.59	.90	2.50	May 19, July 5	3.39	.80
19	Ammonium sulphate 20%	125	June 1, July 15	2.42	.62	1.25	May 19, July 5	2.83	.41
20	Ammonium sulphate 20%,	125				1.25			
	Superphosphate 20%	250	June 1, July 15	2.29	.59	3.00	May 19, July 5	2.52	.30

wise, the elements should become available at a time when the plant can utilize them. Tables II and III present composite data for all fertilizers applied at the different periods and for each fertilizer applied at all periods. They may be used to give a clearer picture than a perusal of the figures in Table I. A few important facts may be tentatively derived from the data.

TABLE II—AVERAGE INCREASE IN TRUNK DIAMETER PER SECTION

Section	Plots	Average Increase in Trunk Diameter		
		1933 (Cms)	1934 (Cms)	1933–34 (Cms)
Fertilizer applied in fall	2–3–4–5	.68	.83	.76
Fertilizer applied in fall and July	7–8–9–10	.69	.62	.66
Fertilizer applied in spring	12–13–14–15	.63	.47	.55
Fertilizer applied in spring and July	17–18–19–20	.75	.57	.66
Controls	1–11	.49	.69	.59

TABLE III—AVERAGE INCREASE IN TRUNK DIAMETER PER TYPE OF FERTILIZER APPLIED

Fertilizer	Plots	Average Increase in Trunk Diameter		
		1933 (Cms)	1934 (Cms)	1933–1934 (Cms)
12–6–4	2–7–12–17	.66	.77	.72
6–6–4	3–8–13–18	.72	.57	.65
Ammonium sulphate 20%	4–9–14–19	.59	.49	.54
Ammonium sulphate 20% Superphosphate 20%	5–10–15–20	.77	.65	.71

It is apparent that adequate rainfall is necessary for a favorable reaction from fertilizer applications. Such has not been the condition during the period of this test. It is probable that the relatively poor growth of the spring fertilized section in 1933 and in all except the fall section in 1934 is due to insufficient moisture. Following a very dry spring in 1933 the applications were not made until June 1 and then a period of over 3 weeks elapsed without sufficient rainfall to carry the fertilizer into the soil. Adequate rains followed the summer and fall applications. The exceedingly dry spring and fall seasons accounts for the poor growth during 1934.

The most marked increase in growth in 1934 occurred in the fall fertilized plots. This is due to a residual effect of the applications made in the fall of 1933. Wyman (2, 3) has shown a similar effect even with relatively quickly available fertilizers.

The data recorded in Table III would appear to show that applications of a complete fertilizer high in nitrogen and ammonium sulphate plus superphosphate were most beneficial. The reasons for the appar-

ent superiority of ammonium sulphate plus superphosphate over ammonium sulphate alone is not clear from this study. Wyman (1, 2, 3) found a similar situation with his study of pin oak fertilization. The explanation may be the influence of phosphorous on the availability or the absorption of nitrogen in the form of ammonium sulphate or the phosphorus may exert its influence upon root growth which is later manifested in greater top growth.

The poor growth response of trees fertilized with ammonium sulphate may have been due to root injury caused by the fertilizer. If this were true it was not manifested in the condition of the foliage. The small applications made in 1933 would seem hardly sufficient to cause injury. Furthermore, the plot receiving applications of ammonium sulphate in both spring and July showed greater growth than the plot fertilized only in the spring.

The variable conditions surrounding such fertilizer investigations make it necessary to carry the test throughout a long period of years before definite conclusions can be drawn. The facts mentioned herewith should be further verified.

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Physiological Studies of Uneven Ripening of Concord Grapes[1]

By FRANK B. CROSS and JAMES E. WEBSTER, *Oklahoma A. & M. College, Stillwater, Okla.*

IN many parts of the United States, the fruit of the Concord grape vine ripens irregularly. This trouble is prevalent throughout the Southwest. In Oklahoma the fruit ripens so unevenly as to very seriously affect the income from commercial vineyards. Uneven ripening in this connection refers to the irregular color of the berries on clusters. Some of the berries at the time when the fruit should be harvested are purple, some red and some green. Naturally it is desirable from the marketing standpoint for all of the berries to be a uniform purple color.

An investigation of this problem has been in progress for several years. It has now assumed two phases, one a study of environmental factors, the other a study of chemical factors. In this paper, the procedure followed in the study of environmental factors will be briefly outlined, and some conclusions drawn. The same course with reference to the chemical factors are presented in an accompanying paper by Webster, Anderson, and Cross.

METHODS

Owing to the importance of light in photosynthesis, attention during the early period of the investigation was directed to its effect upon the problem. Systems were devised both to shorten and to lengthen the daily period of illumination. Plants were covered at 3 p. m. with a box which excluded light and uncovered at 8 a. m., thus shortening the daily period of exposure to light. This system was operated for 6 weeks previous to harvesting. Another set of plants was provided with a longer period of light than normal by suspending over each plant a 100-watt light bulb, the system being equipped with an automatic switch which caused the operation of the lights from 10 p. m. until 3 a. m. This treatment was continued daily for 2 months previous to ripening. In another case a group of plants was partially shaded by means of a cheesecloth which did not exclude light but reduced its intensity. Ordinary light-weight cheesecloth was supported upon a roof-like frame above the plants and at a minimum distance of 1 foot above them. A similar arrangement was used upon another group of plants substituting doplex (a nitro-cellulose glass substitute) for cheesecloth. In this latter case, the quality of the light reaching the plants differed from that under cheesecloth shade and from sunshine or natural light.

Apparatus for cooling the atmosphere and increasing relative humidity was devised for use around another set of plants. This consisted of a water-filled trough in which was submerged the upper edge of a strip of birdseye muslin. This muslin extended downward

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from the trough and was supported by a frame in such a manner as to cause the lower edge to be submerged in another trough supported at the surface of the ground. The upper trough was supported at a height of 5½ feet. Water in each trough was maintained at a permanent level by means of floating valves. With this arrangement, the plants were enclosed upon all sides by wet cloth from which water evaporated at a rapid rate. As a result of evaporation, the temperature within the compartment was lowered about 5 degrees F and the relative humidity increased approximately 25.

Some plants were irrigated with the aid of perforated pipes placed in the soil 8 inches beneath the surface. The perforated pipes were attached to the city water system, the proper amount of water for irrigation being admitted through a cut-off valve. The soil around the plants was kept continually moist but not wet.

Several soil treatments were made. In one case, nitrate of soda was used as a fertilizer at the rate of 10 pounds per plant applied on the soil surface in March. To another set of plants, superphosphate at the rate of 15 pounds per plant was applied at the same time. The superphosphate was suspended in water in a spray tank and forced under pressure into the soil by means of a jet or solid stream nozzle connected with a power sprayer. This method of application was used to insure distribution of superphophate throughout the soil and to avoid fixation at or near the surface. To another series of plants, granulated sugar was applied in the same manner and rate as nitrate of soda. The object in this case was to increase the supply of organic material in the soil in order to increase the food supply for developing organisms which would in their development make use of all of the available nitrogen in the soil, thus withholding nitrogen from the plants.

Another series of tests was designed to determine the effect upon color development of a variable foliage area and a variable amount of fruit upon each cane during the development and ripening of the fruit. This series was divided into five groups, regulating the number of leaves and clusters to develop upon each group. The plant was adopted as the unit. In one case the canes were permitted to grow normally, all clusters in excess of one being removed from each cane. In another series, the number of clusters per cane was reduced to two and the end of the cane removed after five leaves had developed and in another series with two clusters per cane, the tip of the shoot removed after 10 leaves had developed. In another series, the ends of the canes were removed after five leaves had developed in one case and after 10 leaves had developed in another, one cluster of fruit only being left on each of them.

In another series, which is the last, plants of the Concord variety were grafted upon different root stocks in order to determine the effect of the root stock upon uneven ripening.

Data upon the effect of each method of treatment were secured by counting at the time of maturity the number of black, red and green berries upon each cluster of grapes. In cooperation with the Department of Agricultural Chemistry, chemical tests also were made which will be reported upon as referred to earlier in this paper.

Results

In Table I the average percentage of purple grapes for the years 1932–34, is shown for each method of treatment.

TABLE I—Effect of Treatment Upon Percentage of Purple Grapes Produced

Treatment	Percentage Purple Grapes, 1933–34 (Ave.)
One cluster, not tipped	81.7
Nitrogen fertilizer	73.26
One cluster, 10 leaves	73.38
Humidity and temperature apparatus	75.5
Sugar as fertilizer	73.39
Superphosphate as fertilizer	67.06
Muslin shade	62.58
Two clusters, 10 leaves	68.08
Grafted plants	65.86
Doplex shade	62.47
Check, no treatment	64.16
Excess light	62.36
Dense shade	58.96
One cluster, 5 leaves	39.13
Irrigation	45.32
Two clusters, 5 leaves	34.92

Discussion

A comparison of data indicates that manipulations of environmental factors which tended to extend, protect or conserve the leaf area of the plant per cluster of fruit gave the highest percentage of purple grapes at the time of harvesting. Treatments which tended to reduce or restrict the leaf or foliage area of canes and plant invariably tended to increase the number of unripe or uncolored berries at the time of harvest.

Under those treatments which resulted in the development of a leaf area per cluster greater than normal will be found (a) clusters per cane reduced to one upon normal canes and upon canes with 10 leaves, and also canes having two clusters and 10 leaves, and (b) nitrogen and superphosphate as fertilizer. The percentage of purple fruit for each of the treatments was greater than that produced by normal untreated plants.

Under those treatments which conserved the foliage by protecting from hot sun and low humidity, the percentage of purple fruit was greater than that borne by untreated plants.

Under those treatments which caused a reduction of foliage below normal and which at harvest yielded less purple grapes are: the reduction of foliage to five leaves per cane in one treatment, the cane bearing one cluster of fruit and in another two clusters of fruit. The dense shade treatment may also be included in this group because the amount of light allowed evidently was inadequate.

In the chemical tests the amount or percentage of sugar present in the grapes had a definite effect upon ripening, seven per cent or

more of sugar being required for proper ripening. Since sugar synthesis takes place in the leaves, we may assume that a more extended leaf area may produce more sugar and therefore decrease tendency to uneven ripening. This would seem to be in accord with data secured upon manipulation of environmental factors in which a restriction of leaf area per cluster increased the tendency to uneven ripening and an increase in leaf area in proportion to fruit decreased the tendency to uneven ripening.

A further study of the problem is being made to determine reason for apparently inefficient photosynthetic activity under southwestern climatic conditions.

Chemical and Enzymatic Studies of the Uneven Ripening of Concord Grapes[1]

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THIS article is a partial report of the chemical studies that have been made in endeavoring to find the explanation of the uneven ripening of Concord grapes. There is little difficulty in finding in the literature comprehensive analyses covering most of the readily determinable changes that take place in grapes as the clusters mature. Most of this work, however, has stressed the factors dealing with the most profitable and satisfactory time to harvest the crop, and only minor attention has been paid to the changes occurring at time of coloring. Our problem, then, is not so much to follow the changes which take place as grapes ripen, as to determine what chemical changes are associated with the inception of color in grapes. Probably the most comparable work is that of Lewis (5) although he does not report analyses of Concord grapes. He finds that there is less than one per cent of dextrose present before "verasion" but thereafter dextrose increases rapidly. Levulose first appears at "verasion" and then increases for a time equally with dextrose and finally continuing to increase after dextrose has ceased to gain. In his work it also is shown that acidity increases up to the "verasion" after which it declines. In general, the sugar content of Concord grapes increases and the acidity decreases as ripening progresses (8).

METHODS OF SAMPLING

Samples of the grapes were secured by clipping clusters from the vines used for physiological studies (See accompanying paper by Cross and Webster). Samples were collected in every case between 7:30 and 8:00 a.m., and were immediately brought into the laboratory and separated into three groups, namely, (a) Green, no trace of purple; (b) colored, a definite purple shade; and (c) ripe, fully colored. For the enzyme studies the colored class was combined with the ripe samples.

Between 5 and 10 pounds of grapes were secured for each sample, requiring 30 or more clusters of the size used. After sorting and weighing, part of the grapes were run through a coarse food chopper of such size as not to crush the seeds, and then the juice was expressed, using a Carver laboratory press. Immediately following this, the juice samples were centrifuged and aliquots immediately measured out for the various determinations. In all, about 2½ hours elapsed before all analyses could be started. While the juice samples were being prepared, other grapes were being stored in 80 per cent alcohol by the conventional methods. Samples of whole grapes also were used for moisture determinations.

Chemical methods and enzyme tests:—Specific gravity determinations were made at 15.6 degrees C using a Westphal balance. Acidity

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was determined by titrating 10-millimeter samples with 0.1 N alkali and the figures in the tables represent the titration value. The quinhydrone electrode was used in making the hydrogen ion determinations. Total tartaric acid determinations were made according to the A. O. A. C. (1). Astringency and related materials were determined essentially as done by Caldwell (2). Reducing sugars were determined in the usual manner on clarified aliquots of the extracts, using the Shaffer-Hartman procedure and the results were calculated as invert sugars. For the total sugar determinations samples were inverted using invertase and then the determinations were made as for reducing sugars. Dextrose was estimated using the procedure outlined in the article by Lothrop and Holmes (6).

Enzyme tests:—Iodine reduction, methylene blue reduction, and peroxidase, were determined according to the directions of Miller (7). Oxidase was determined according to Guthrie's (4) method. Catalase was run on 5 ml neutralized samples, following the procedure of Davis (3).

Discussion

The data in the first table show the partial analysis of whole grapes sampled at the same time that material was secured for the juice samples. The results show that the sugar percentages for the whole fruit are quite comparable with that of the juice, thus removing the necessity of separate sugar analysis of whole fruit in order to secure a picture of the conditions as they exist in the growing fruit. More directly bearing on the problem is the result shown in this table, as well as in the following one, that under Oklahoma conditions Concord grapes do not color until they contain at least seven per cent of total sugars, which figured on the basis of our present work, may be set as a minimum for inception of color. In no instance did full color develop with a sugar content of less than eight per cent. Mention may

TABLE I—Chemical Analysis of Whole Concord Grapes at Different Stages of Ripeness, 1934
(Percentages on Basis of Fresh Weight)

Date of Samples	Color (Percentage of Berries in Color Class)	Water	Ash	Sugars	
				D. Red.	Total
		Sample Green			
Aug. 9......	31.7	86.54	.604	5.70	5.70
Aug. 16.....	22.2	87.13	.645	5.88	6.00
Aug. 23.....	17.3	86.89	—	5.95	5.95
		Sample Colored			
Aug. 9......	25.9	84.84	.630	8.24	8.32
Aug. 16.....	28.6	84.81	.743	8.08	8.41
Aug. 23.....	26.6	84.76	—	8.56	8.68
		Sample Ripe			
Aug. 9......	42.4	84.11	.654	9.38	9.63
Aug. 16.....	49.2	83.64	.822	8.93	9.19
Aug. 23.....	56.0	83.01	—	9.33	9.87

also be made of the fact that there is a continual decrease in the percentage of uncolored grapes during ripening. However, it is not feasible to wait to harvest the grapes when all fruits have colored, for by that time the riper berries will have disintegrated and abscissed. Nevertheless, the date shown for the last sampling in every case is later than the commercial harvest time for that particular season, showing that some delay is possible.

The data presented in Table II represent more complete analyses, secured by analyzing the pressed juice. The sugar data in this table emphasize chiefly the dextrose-levulose ratio, which shows a preponderance of levulose in the green and colored fruit and a striking change in the ripe fruit to near equality of the two sugars. At present no explanation can be advanced to cover this point and future work on this ratio is indicated. Attention might also be directed to the relatively low sugar content of even the ripest grapes. Unpublished data from other years show that the composite juice from check samples has analyzed as low as nine per cent in sugars, which figure is in striking contrast to the 15 to 20 per cent of sugars often reported from Ohio and New York (8).

Peculiarities of an analytical nature appear when the total sugar figures for the whole, green grapes and green grape juice are compared. No sucrose appears in the samples preserved in alcohol while the juice shows appreciable amounts. Apparently there is inversion of sucrose when samples of the strongly acid, green grapes are stored in alcohol. Small but definite amounts of sucrose appear under all conditions in the fresh juice.

Tartaric acid and astringency figures do not seem to show any unusual trends which might explain the coloring phenomena. On the basis of these figures, acidity might seem to be an important factor but data from other years indicate that the earliest ripe grapes are often more acid than are the green grapes at the end of the test period. Even so, acidity may have to be considered along with other factors in the final explanation of the uneven coloring.

The enzymatic work presented in Table III shows some interesting results. Since methylene blue reduction is absent and the iodine reduction values are small and do not show great differences, reducing enzymes, on the basis of the amount present, would seem to play only a small part in the ripening of grapes. Oxidase activity, as determined by Guthrie's (4) method is also very low and variable and in some tests has been found absent. Conversely peroxidase activity has been found to be present in large amounts and apparently in greater amounts in the green than in the ripe grapes; however, only a very small sample of juice could be used due to the high activity and this, combined with the fact that the ripe samples were compared only with the green samples precludes a positive statement of values. Catalase activity is definitely much higher in the colored grape juice than in the green juice. A peculiarity in this respect was noted in comparing unneutralized juice of both kinds, that the green juice gave as high a catalase value as the ripe juice, thus indicating the necessity of carefully examining the acidity relations in respect to enzyme activity.

TABLE II—CHEMICAL COMPOSITION OF PRESS JUICE OF CONCORD GRAPES (1934)
(Unless otherwise stated percentages are calculated on a fresh weight basis)

Date of Samples	Color Per cent of Whole	Sp. Gr.	Acidity N/10 Alk. for 10 Ml.	pH	Solids (Per cent)	Sugars		Dex-trose	Levu-lose	D:L Ratio	Tartaric Acid (Gms per 100 Ml.)	Astringency		
						Red	Total					Total (Gms per 100 Ml.)	Non-Tannins (Gms per 100 Ml.)	Tannins (Gms per 100 Ml.)
						Sample Green								
Aug. 9.....	31.7	1.0390	15.2	3.13	7.08	5.39	6.65	2.63	2.84	.93	1.164	.218	.129	.089
Aug. 16....	22.2	1.0410	12.9	3.25	7.58	5.84	6.19	2.29	3.74	.61	1.207	.185	.106	.078
Aug. 23....	17.3	1.0390	12.0	3.25	7.16	5.89	5.89	2.43	3.49	.70	1.053	.162	.098	.064
						Sample Colored								
Aug. 9.....	25.9	1.0502	12.5	3.23	9.46	7.61	8.77	3.36	4.23	.79	1.104	.221	.131	.090
Aug. 16....	28.6	1.0520	10.8	3.42	9.61	8.37	8.71	3.65	4.74	.77	1.069	.185	.119	.066
Aug. 23....	26.6	1.0500	9.1	3.35	8.87	8.50	8.59	3.50	5.05	.69	.955	.139	.083	.056
						Sample Ripe								
Aug. 9.....	42.4	1.0600	10.9	3.33	10.86	8.19	9.78	4.18	4.01	1.04	1.113	.215	.135	.080
Aug. 16....	49.2	1.0600	8.5	3.57	10.73	8.75	10.05	4.10	4.67	.88	1.092	.206	.119	.087
Aug. 23....	56.0	1.0563	7.4	3.55	9.88	9.39	10.00	4.70	4.75	.99	.855	.164	.091	.072

TABLE III—ENZYMES IN PRESS JUICE OF CONCORD GRAPES, 1934

Date of Samples	Color Per cent of Whole	Iodine Reduction 5 Ml. Juice	Methylene Blue Reduction	Peroxidase (Miller) 1 Ml. Juice	Oxidase (Guthrie) 5 Ml. Juice	Catalase 5 Ml. Juice
			Sample Colored			
Aug. 14	73.5	.3 ml.	——	+++	Trace	2.7
Aug. 21	76.0	.3 ml.	——	+++	.97 ml.	5.2
Aug. 27	79.3	.2 ml.	——	++	.21 ml.	4.1
			Sample Green			
Aug. 14	26.5	.2 ml.	——	++++	Trace	.9
Aug. 21	24.0	.2 ml.	——	++++	.30 ml.	1.7
Aug. 27	20.7	.1 ml.	——	+++	.21 ml.	2.0

Reviewing briefly the data presented, it is found that the chief chemical difference between colored and uncolored grapes lies in the much lower sugar content of the green grapes. Catalase activity was found to vary greatly between the green and colored grapes and this alone of the enzymes activities examined seem to show a correlation with the color results.

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Grape Root Distribution Studies

By F. N. HARMON and ELMER SNYDER, *U. S. Department of Agriculture, Fresno, Calif.*

AT the United States Experiment Vineyard, near Fresno, California, during the fall of 1933, 32 vines of Vinifera grape varieties grafted on various Phylloxera resistant rootstocks were dug out and a study made of the distribution and concentration of the roots. The vines, planted 8 feet apart each way, were in a healthy condition, and were approximately 25 years old, when excavated. The annual rainfall of 8.61 inches has been supplemented by irrigation as needed. All vines had received clean summer cultivation, with a winter cover-crop some seasons. The water table stood at 15 feet 6 inches from the soil surface at the time the vines were dug.

The soil type is designated as a San Joaquin sandy loam, and is an outlying portion of soil of this character. The San Joaquin sandy loams are mostly confined to the eastern side of the San Joaquin and Sacramento Valleys, where 346,000 acres have already been mapped. The soil is light brown to reddish in color, granitic in origin, and composed of sharp angular particles. The top soil to a depth of 6 to 12 inches is an adhesive sandy loam underlaid by a free sandy loam subsoil which extends to hardpan, becoming distinctly more sandy just above the hardpan layer. In the plot where these studies were made, the hardpan varied from 3 to 7 feet from the surface, the exact depth under the vines examined being recorded in Table I. Soft and porous spots occurred in the hardpan into which some roots penetrated.

Since the vines were planted 8 feet apart each way, a circle 8 feet in diameter was laid out around each vine as a center. Two stakes were driven about 12 feet apart outside of the circle and their tops leveled so that by sighting over these stakes the depth in the excavated hole could be accurately checked with the soil level at any time. The soil was carefully removed in 6 inch increments. It was found that screening the soil to obtain the roots was not satisfactory because the soil clogged the screens, so the loosened soil was spread thinly and all roots recovered and graded. The roots were segregated into fine (0–¼ inch in diameter), small (¼–½ inch), medium (½–1 inch), and large (over 1 inch in diameter). The size, horizontal spread, vertical penetration, and weight of roots were recorded. The angles of the main roots were obtained by a level and protractor. Any roots from adjacent vines which entered the excavated hole were kept separate, weighed, and recorded as foreign roots. The principal roots and their main branches of each vine were recorded diagramatically.

Table I gives a summary of the root distribution for the various varieties and stocks, based on each foot of depth. There is a rather clear-cut difference in the root distribution on different stock varieties. For example, regardless of the variety top worked, the Australis, Salt Creek, and Riparia Grand Glabre stocks were relatively shallow-rooted, most of the roots being in the top two feet of soil. The

Variety and Stock	Age of Vine (Yrs.)	De-th to Hardpan (Ins.)	Root Weight Concentration per Foot of Depth (Per cent)					Total Weight Roots per Vine (Gms)
			1st Ft.	2nd Ft.	3rd Ft.	4th Ft.	5th Ft.	
Ohanez on Australis	25	64	37.2	58.5	4.3	—	—	5,230
Sultanina on Australis	25	66	64.9	35.1	—	—	—	4,044
Ohanez on Berlandieri x riparia, No. 420-A	25	63	37.5	37.5	20.1	5.0	—	7,429
Sultanina on Berlandieri x riparia, No. 420-A	23	66	39.3	36.8	20.5	3.4	—	4,838
Ohanez on Constantia	25	60	43.4	49.0	7.0	.6	—	7,040
Sultanina on Constantia	25	72	28.4	45.3	18.9	7.4	—	10,032
Ohanez on Viala	22	60	7.0	36.7	50.0	6.3	—	12,202
Sultanina on Viala	25	60	29.0	45.2	19.5	6.3	—	18,332
Feher Zagos on Dog Ridge	28	51	11.6	27.0	38.6	16.3	6.5	11,859
Feher Zagos on Dog Ridge	28	51	19.1	35.2	28.7	14.9	2.2	9,032
Malaga on Dog Ridge	28	54	8.7	33.4	46.8	7.6	3.5	10,657
Malaga on Dog Ridge	28	54	8.3	45.4	29.0	13.8	3.5	14,949
Muscat St. Laurient on Dog Ridge	29	36	42.2	52.2	5.5	*	*	4,478
Muscat St. Laurient on Dog Ridge	29	32	51.0	34.4	14.2	*	*	5,343
Corinthe a Gros Grain on Mourvedre x rupestris, No. 1202	26	58	2.6	47.1	41.3	8.6	.5	13,968
Aneb el Cadi on Riparia Grand Glabre	26	58	74.0	26.0	—	—	—	3,977
Olivette Blanche on Riparia a Grandes Feuilles	26	64	4.6	46.4	34.9	14.2	—	4,198
Corinthe a Gros Grain on Riparia x rupestris, No. 3309	26	52	11.2	70.3	18.4	—	—	8,492
Corinthe a Gros Grain on Riparia x rupestris, No. 3309	26	48	7.4	69.4	22.7	.5	—	8,461
Corinthe a Gros Grain on Riparia x rupestris, No. 3309	19	57	44.1	56.0	—	—	—	8,156
Feher Som on Rupestris St. George	25	36	32.4	46.2	19.2	1.7	—	2,976
Hebron on Rupestris St. George	25	88	32.5	59.5	6.4	1.6	—	5,078
Hebron on Rupestris St. George	25	68	11.2	79.0	7.8	2.0	—	4,536
Hycales on Rupestris St. George	26	54	17.9	69.4	12.0	.7	—	5,157
Inzolia Bianca on Rupestris St. George	26	48	20.5	50.9	27.8	.9	—	4,593
Muscat Bonod on Rupestris St. George	26	54	3.2	50.5	41.2	5.2	—	6,218
Muscat noir Precoce on Rupestris St. George	26	60	7.1	71.9	19.3	1.8	—	6,855
Sultana on Rupestris St. George	26	60	9.2	54.2	31.3	5.2	—	7,278
Aramon on Salt Creek	26	46	42.0	49.5	8.6	—	—	3,839
Flame Tokay on Salt Creek	25	42	22.4	50.1	26.7	—	—	3,542
Hebron on Solonis x Othello, No. 1613	25	48	7.8	51.9	35.8	4.5	—	7,907
Hebron on Solonis x Othello, No. 1613	26	48	6.5	48.6	37.7	7.3	—	8,878
Average of all vines	25.6	55	20.8	47.9	24.8	5.6	.8	7,487

*Root penetration limited by hardpan.

stocks Berlandieri x riparia, No. 420-A, Constantia, Riparia x rupestris, No. 3309, and Ruppestris St. George were generally well rooted through the top three feet with some roots extending into the fourth foot. Dog Ridge, Mourvedre x rupestris No. 1202, Riparia a Grandes Feuilles, Solonis x Othello, No. 1613, and Viala were still deeper-rooted with a fairly good distribution of roots down to hardpan. On the whole, Dog Ridge appeared to be the deepest-rooted of any variety.

This root distribution apparently varied largely with the stock. While the total weight of roots on any combination varied both with the stock and with the vigor of the top variety, the tendency toward deep or shallow rooting apparently was determined largely by the stock variety.

In the first eight combinations shown, the total weight of roots varied widely with the different stocks. For example, Australis with Sultanina top had only about 4,000 grams of roots while Viala with Sultanina top had more than 18,000 in the same soil area. On the other hand, the vigor of the top variety was also an important factor in determining the amount of root growth. Malaga, a strong-growing variety on Dog Ridge, showed a total root weight of 10,657 and 14,949 grams on two individual vines. Muscat St. Laurient, a weak-growing variety on Dog Ridge on somewhat shallow soil, however, showed 4,478 and 5,343 grams of weight of roots on the two vines. In general, within the same stock, root weight was highest with the more vigorous tops. On the other hand, within the same top variety, root population varied greatly both as to depth of roots and total weight of roots in the different stock varieties.

Fig. 1 illustrates graphically the depth of distribution of total, fine, and foreign roots. As shown in this curve, the distribution of the fine roots closely follows the distribution of total roots. Foreign roots show slightly deeper penetration indicating that the roots farther from the vine tend to extend a little deeper.

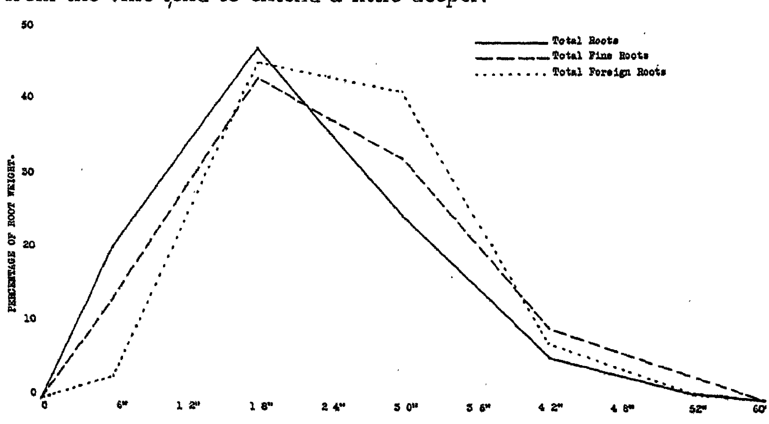

FIG. 1. Vertical distribution of total, fine, and foreign roots. (Average of 32 vines)

Some effort was made to determine the lateral spread of roots. Roots from adjacent vines were always found coming into the excavated hole. In fact these foreign roots made up 36.7 per cent of all roots recovered. On the other hand, some roots always extended beyond the 8-foot excavation. More exact information was obtained by following one main root of Solonis x Othello, No. 1613 a distance of more than 19 feet and which still had a diameter of ¼ inch when it was impractical to follow it further. Twelve side branches from this one root were followed an average distance of over 10 feet and still were from ⅛ to ⅜ inch in diameter when cut off. With this indication of lateral root spread it is apparent that under similar conditions experimental soil treatments require rather large areas or more than one buffer row if differential treatments for the whole root zone are to be developed.

Vinifera Grape Cion Influence on Dog Ridge Stock

By ELMER SNYDER, and F. N. HARMON, *U. S. Department of Agriculture, Fresno, Calif.*

DURING the past year when some vines were being pulled, an opportunity was afforded to study Dog Ridge rootstock grafted with several Vinifera varieties. The Dog Ridge stock was planted in 1903 and was grafted in 1905 with the Vinifera varieties. After 29 years, this block of vines at the United States Experiment Vineyard, Fresno, California, was still growing in a healthy condition. The soil in this plot, a San Joaquin sandy loam, was quite uniform.

The trunks of 116 vines were sawed off horizontally sufficiently above and below the graft union swell to obtain a typical cross-section of cion and stock. The cross-sections were traced on paper and their areas obtained by the use of a planimeter. The areas of the cross-sections were taken as a fair indication of the growth of stocks and cions over the 29 year period. Tufts (1) under California conditions found a correlation of as high as 0.92±.007 between the circumference of trunk and weight of top of peaches.

Table I gives the summarized data of the cross-section measurements of cion and stock areas. Twelve Vinifera varieties varying in growth habits from strong to weak growers were represented in the 116 vines studied. A study of the data indicates that in a majority of the bud unions the cion was larger than the stock. In the case of two varieties, namely, Muscat Rose and Malvasia Rosario, the stock area exceeded that of the cion. In addition to the data given in Table I, 154 miscellaneous unions, including 31 Vinifera varieties and 16 stocks, were measured. In the majority of these unions, the cions were larger than the stocks, the mean area of the stock cross-sections averaging only 60.1 per cent of that of the cions. The larger probable error in the case of Muscat St. Laurient and Hunisa in Table I would indicate that other factors have undoubtedly affected these vines. In the ma-

TABLE I—VINIFERA GRAPE CION INFLUENCE ON DOG RIDGE STOCK AREA

Cion Variety	No. of Vines	Cross Section Measurements (Sq. In.)		Per cent Stock Area is of Cion
		Mean Area of Cion	Mean Area of Stock	
Malaga	12	14.33± .364*	12.42±.567*	86.7
Hunisa	10	17.60±1.202	9.50±.678	54.0
Kadarka	8	12.88± .561	8.25±.425	64.1
Mission	8	12.13± .547	6.75±.343	50.7
Pedro Ximines	10	11.60± .803	6.20±.448	53.5
Servan Blanc	10	10.70± .529	7.30±.380	68.2
Malvasia Rosario	10	8.00± .418	9.40±.574	117.5
Luglienga Nera	10	7.10± .305	5.80±.331	81.7
Feher Zagos	12	6.42± .351	4.83±.261	75.2
Gros Verdot	10	9.00± .819	8.80±.768	97.8
Muscat St. Laurient	6	12.17±1.198	5.00±.643	41.1
Muscat Rose	10	4.60± .180	4.80±.252	104.4
Average of all vines	—	10.40± .291	7.62±.208	73.3

*Indicating variability only.

jority of cases however the larger cion area has exerted a marked influence on the stock size. The correlation between the area of the stock and the area of the cion was .59±.041. While this correlation is not definitely high, considering the period of growth of 29 years and the number of varieties and vines included, it would seem significant.

There are some outstanding facts in connection with the data. Vinifera grape varieties grafted on Dog Ridge rootstock were in an excellent condition at 29 years of age. The average stock size was 73.3 per cent of that of the cion, denoting a general cion overgrowth with the Dog Ridge stock. The correlation between the size of stock and the size of cion as judged by the cross-section areas was .59±.041. While some other factors undoubtedly enter in, a study of the data indicates that the more vigorous cion varieties have resulted in stocks significantly larger than the average and the weaker cion varieties have resulted in stocks significantly smaller than the average.

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Empty-seededness in Varieties of *Vitis vinifera*

By H. P. Olmo, *University of California, Davis, Calif.*

In germinating seed from many vinifera grape varieties during the past three years, marked varietal differences were noted. Thus the seed of Chaouch, an important table grape in Turkey, Greece and the Crimea, seldom produced more than three or four per cent of seedlings. At the other extreme were Muscat of Alexandria and Emperor, which often produced an 80 per cent seedling stand. Differences of seed treatment before germination, such as altering the duration and temperature of stratification, failed to give good seedling stands with varieties that had regularly shown poor germination.

Of approximately 20 varieties investigated that showed low seed viability, all were exceptional in that a large number of the mature seeds were "empty." Of the seeds saved for planting, two classes were segregated, namely, those that floated on water and those that did not. The seeds that floated have been designated "empty"; but examination of the seed lumen always revealed some shriveled tissue, occupying a variable portion of the cavity. In addition many, if not all, seeded varieties produced ovules that aborted at various stages of development. These early-abortive ovules lacked bony seed coats and seldom approximated the size of a fully matured seed. This phenomenon does not form a part of the present discussion, although it may be correlated with empty-seededness, at least in some varieties.

Plant breeders and others who propagate the vine from seed recognize that hollow seeds rarely germinate and often eliminate such seed. Viala and Ravaz (3) advocated separation and selection by placing the seed in water and noted that "bad seeds float, good seeds sink to the bottom." Beach (1) in 1903 noted a correspondence between the specific gravity of the seeds and the germination and vigor of the seedlings in the American hybrids Empire State and Canada. In the former variety no germination occurred with seeds of less specific gravity than 1.045 and only weak germination below 1.065. The data were fragmentary. Empty seeds rarely germinate. In 1932, of 304 seeds of Ribier that floated in water, none germinated, whereas the seed that sunk gave from 62 to 86 per cent germination. That poor germination of many vinfera varieties is largely attributable to the presence of seeds with degenerated contents is further substantiated by the data of Table I. The varieties are arranged in increasing order of viability. The samples with a high proportion of empty seeds are those that are poorly viable. A few seeds of the variety Chaouch, even though light enough to float in water, are capable of germination. In planting seeds of such a variety it would be unwise to discard those that floated.

The questions of interest center about the factors responsible for empty-seededness. Data collected at this station by Professor F. T. Bioletti in 1930 and by Dr. Helen Pearson in 1931 and 1932 have been incorporated in Table II to supplement records of the author. During the 1933 and 1934 seasons, samples of three to four clusters were taken at random from several vines, not always in the same location in the vineyard. The seeds were extracted by hand, washed, and

TABLE I—GERMINATION PERCENTAGES OF A NUMBER OF VINIFERA VARIETIES AND THE CORRESPONDING PERCENTAGES OF EMPTY SEEDS IN THE SAMPLE

Variety	Year	Percentage of Empty Seeds	Percentage Germination
Chaouch	1931	99.2	2.0
	1932	99.2	4.2
Burgrave	1931	66.8	2.2
Damas Rose	1931	66.7	14.8
Dattier	1932	65.6	16.5
Tokay	1932	50.5	34.5
Ribier	1931	47.3	40.4
Diamond Jubilee	1932	36.7	53.0
Olivette blanche	1932	32.1	56.3
Rambola	1931	12.0	58.5
Hunisa	1931	12.6	59.1
Molinera	1932	23.6	65.7
Muscat Blowers	1932	6.0	68.6
Emperor	1932	16.9	69.0
Muscat of Alexandria	1932	5.7	84.5

dried at room temperature. The total number of seeds in each sample varied from 200 to 1,200. The 1930 and 1931 collections were made without the present study in mind, so that the size of the samples was small. In addition, some seeds were obtained from cross-pollinated ovaries, on bagged clusters. It will be noted that the per cent of empty seeds is considerably higher in such cases. Of three lots of Tokay seed collected in 1932, the one secured from bagged clusters had approximately 50 per cent of empty seeds. Two other samples of 1,200 seeds each; from unbagged clusters, gave about 30 per cent, an indication that conditions within the bags, possibly higher temperature, markedly increased the number of seeds classified as empty.

The variety Chaouch consistently produced empty seeds over the 5-year period. The average was 99.5 per cent. Dattier produced over

TABLE II—PERCENTAGES OF EMPTY SEEDS IN SOME VINIFERA VARIETIES DURING DIFFERENT SEASONS

Variety	Percentage of Empty Seeds					
	1930	1931	1932	1933	1934	Average
Chaouch	99.2	99.2	100.0*	100.0	99.0	99.5
Dattier	—	—	65.6*	52.9	54.8	57.8
Diamond Jubilee	26.0	—	36.7*	—	30.6	31.1
Emperor	0.0	—	16.9*	—	1.6	6.2
Hunisa	—	9.0	5.9	12.6	29.1	14.1
Madresfield Court	15.0	8.2	7.8	15.2	8.9	11.0
Molinera	—	—	23.6 28.8	28.3	8.6	22.3
Muscat of Alexandria	3.0	—	5.7	7.3	6.7	5.7
Muscat Blowers	7.0	—	6.0	7.0	3.5	5.9
Olivette blanche	—	—	32.1	47.9	31.2	37.1
Ribier	22.0	47.3*	29.3	32.0	41.9	34.5
Tokay	—	67.6*	50.5* 30.2 31.2	—	22.9	40.5

*From cross-pollinated ovaries of bagged clusters.

50 per cent of empty seeds, whereas Muscat of Alexandria, Muscat Blowers, and Emperor yielded a very high proportion of sound seed. The other varieties listed were more or less intermediate. In most cases the results from year to year were of the same magnitude; but some marked fluctuations appeared that were not easily explained. The variety Molinera, for example, with 28 per cent of empty seeds in 1933, had approximately 9 per cent in 1934. This would indicate that environmental factors may be very important in certain seasons, so that the ratio of empty seeds, even though hereditarily determined, may be modified considerably by climate, amount of crop, etc. It seems illogical, however, to attribute the significant differences found between varieties to other than hereditary factors. Progeny grown from the cross Hunisa x Muscat of Alexandria produced a very high proportion of sound seed, whereas most selfed seedlings of the Burgrave, a variety with many empty seeds, exhibited the phenomenon of empty-seededness to a high degree.

Most of the hybrids between Vinifera and other species produced seed that was highly viable, and in general few first-generation hybrids were characterized by the production of a large number of empty seeds. This relationship is illustrated graphically in Fig. 1. Data on the number of empty seeds have been obtained for 243 varieties of *Vitis vinifera* and for 70 varieties which are hybrids between Vinifera and an American species, usually *V. labrusca*. About 40 per cent of the total number of vinifera varieties studied have 10 per cent or less of empty seeds, whereas approximately 58 per cent of the interspecific hybrids fall in this category. Most of the data have been kindly furnished by Professor F. T. Bioletti. The hereditary factor or factors that determine empty-seededness are apparently of a recessive nature, so that in general seeds from F_1 hybrids are more viable than those of the Vinifera parent. This postulate may not necessarily follow from the trend shown in Fig. 1, since the greater number of hybrid varieties having sound seeds may be attributable to the frequent employment of Vinifera parents of high seed viability.

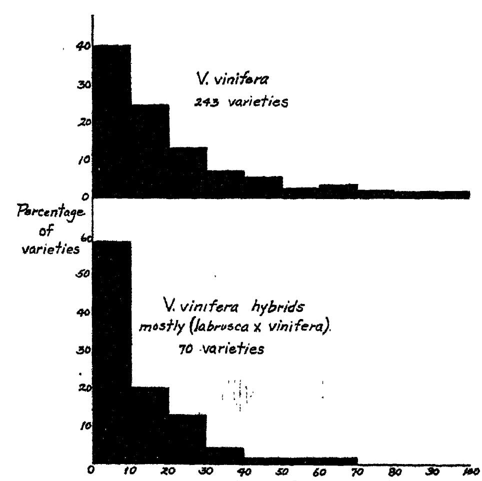

FIG. 1. Varieties of *Vitis vinifera* and its hybrids in relation to the percentages of empty seeds which they produce.

Seeds classified as empty were usually recognizable by an abnormal coloring of the seed coats. The empty seeds of Chaouch were very dark brown, some almost black, whereas

those of Olivette blanche and Diamond Jubilee were often tinged with green, signifying an incomplete maturation of the testa. Seeds that were empty in highly pigmented varieties, such as Ribier, were frequently reddish and stained-looking. Many seeds with degenerated contents and classified as empty were smaller than the normal seed of the variety. This was more likely to be the case in varieties that varied greatly in seed size, such as Molinara and Dattier. In such cases the abortion occurred earlier in development, but not early enough to prevent the formation of bony seed coats.

In the mature Vitis seed the fatty endosperm makes up the bulk of the internal tissue, being snugly enclosed by the folded seed coats. The undeveloped embryo is very small and spindle-shaped, embedded in the endosperm at the micropylar end of the seed. It is seldom more than 1 or 2 millimeters in length. Dissection of "empty" seeds always indicates the previous formation of endosperm tissue, which now appears shriveled and degenerated. In many seeds the remnants of the internal tissue may be desiccated, leaving the seed completely hollow. Embryos have been dissected from some empty seeds, but whether they are always present has not been determined.

The pollen parent exerts no influence in altering the percentage of empty seeds. Chaouch has been repeatedly pollinated with Muscat of Alexandria and Black Corinth pollen, but the percentage of empty seeds is the same as if the ovules were self-pollinated. Empty-seededness is therefore determined by the maternal parent. This is an interesting parallel to the case reported by Tukey (2) in the sweet cherry, where the early-ripening varieties, characterized by embryo abortion, fail to produce viable seed even though pollen of a late variety is used. On the other hand, he finds that pollen of an early variety, used on a late variety, results in normal seed development. From such evidence Tukey has formed the opinion that the production of non-viable seed is not genetic, but is a problem of nutrition and physiology. To say that nutrition and physiology are responsible does not exclude a genetic basis for embryo abortion. The literature is replete with reports of nutritional disturbances that have been shown to be inherited. There is danger of discouraging breeders who are attempting to obtain earlier varieties of cherry by maintaining that the phenomenon of early-ripening is non-genetic. That Tukey believes this is an inherited phenomenon is supported by his statement: "By culturing an embryo from an early-ripening type upon which another early-ripening variety had been used as the male parent, the chances would be increased of securing a new individual with a combination of genes for early-ripening from both male and female parent."

The genetic constitution of the embryo and endosperm may be quite unlike that of the maternal parent that is nourishing them. Consider the cross previously mentioned, when pollen of the Muscat of Alexandria is used to fertilize Chaouch ovules. If we admit that empty-seededness is inherent, then factors for normal seed development are contributed by the pollen of Muscat, whereas factors for abortion are transmitted through Chaouch ovules. With this introduction of genetic factors tending toward normal seed development,

we should sometimes expect the development of embryo and endosperm to proceed to maturity; but such is not the case. "Empty-seededness" is therefore manifested regardless of the genetic constitution of embryo and endosperm. The cause of the abortion is to be sought in maternal tissue; the abortion itself is only secondary.

This same concept may apply to embryo abortion in early-ripening cherry varieties. The cessation in growth of the embryo is a result of disturbances originating in maternal tissues. Although these disturbances may be nutritional in nature, as Tukey (2) has suggested, they are genetically controlled by the mother plant.

Summary

The poor germination of many Vinifera grape varieties may be largely attributed to empty-seededness. Seeds classified as "empty" by their flotation in water rarely germinate. The internal tissue of "empty" seeds consists largely of remnants of the fatty endosperm that have degenerated and left the seeds more or less hollow. Records obtained over a 4-year period for a number of varieties indicate that the phenomenon of empty-seededness is hereditary, although its expression may be modified considerably by environmental conditions. A comparative study of Vinifera varieties and their hybrids suggests that the phenomenon is inherited as a recessive factor complex. The expression of empty-seededness is the same whether the ovaries are cross or self-fertilized. This fact suggests that the cause of empty-seededness is maternal and exterior to the developing zygotes. This concept may also apply to embryo abortion in the sweet cherry, as reported by Tukey (2).

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Breeding for Seedless Vinifera Grapes

By ELMER SNYDER, *U. S. Department of Agriculture, Fresno, Calif.*

A PRELIMINARY report on the breeding of grape varieties of *Vitis vinifera* was made in 1931 (1). Attention at that time was called to the fact that seedless grape varieties were obtained in the F_1 generation seedlings by using a seedless variety as the male parent. Since the issue of the preliminary report more seedlings have fruited giving additional data and some promising seedlings. In the continuation of the Vinifera grape breeding studies, the main object has been the production of more varieties having the seedless character and also to produce a seedless grape with a muscat flavor. To indicate leads for future breeding it seems desirable to give a brief discussion of some of the crosses where seedless Vinifera varieties were used as the male parent.

Muscat of Alexandria crosses:—The Muscat of Alexandria, a white grape, is the variety used for Muscat raisin manufacture. The normal berries are large, oval, and although the stamens are upright, many small, round, seedless berries occur. This variety was crossed with the seedless Corinthe Blanc, Corinthe Rose, Panariti (black Corinthe), Sultanina, Sultanina Rosea, and Black Monukka, all having upright stamens.

Nineteen seedlings were obtained from the Alexandria x Corinthe Blanc cross, 17 of which have fruited. Four of these had reflexed stamens while the remainder were upright. All seedlings were white in color, small in size, not definitely muscat flavor, and none were seedless. This cross did not yield any seedling of apparent value.

Thirty-five seedlings were obtained from the Alexandria x Corinthe Rose cross, 28 of which have fruited. Three vines had reflexed stamens, the remainder upright. Fourteen seedlings were white in color, and 14 varied from light to dark red. The berries were small in size, not definitely muscat in flavor, and none were seedless. While this cross did not yield any seedling of apparent value, one red-fruited seedling has been selfed in an attempt to segregate the muscat flavor and the seedless character.

Twenty-four seedlings were grown from the Alexandria x Panariti cross, 23 of which have fruited. Six vines had reflexed stamens, the remainder upright. Twelve seedlings were white in color and 11 varied from dark red to purple black. The berries varied in size from small to medium large, one seedling had a definite muscat flavor while nine others had a slight muscat flavor. No seedless seedlings were obtained in this cross. Selfed seedlings of two of the more promising vines of this cross have been grown to study segregation of characters.

Six seedlings were obtained from the Alexandria x Sultanina cross, four of which have fruited. One vine had reflexed stamens while three were upright. All seedlings were white in color, small to medium large in size, and not definitely muscat flavor. One vine had seedless fruit while one other vine bore fruit with only hollow rudi-

mentary seeds. Two seedlings have been considered of sufficient value to propagate for production tests. Selfed seedlings have been grown and back crosses made with the male parent.

Eleven seedlings were obtained from the Alexandria x Sultanina Rosea cross, nine of which have fruited. One seedling had reflexed stamens, eight had upright. Five seedlings were white in color while four varied from light pink to red. Three seedlings had a slight muscat flavor, two seedlings were seedless and one near-seedless. One seedling has been propagated for further trial and selfed seedlings have been grown of two vines of this cross.

Fifty-four seedlings were derived from the Alexandria x Black Monukka cross, 43 of which have fruited. Ten vines produced reflexed stamens while 33 were upright. Twenty seedlings were white in color with the remainder varying from white mottled red to pink, and from dark red to purple black. The berries varied from medium to large. Ten seedlings had a slight muscat flavor, six seedlings were practically seedless, one of which had the combined characters of muscat flavor and seedlessness. Six seedlings of this cross have been propagated for further trials while eight seedlings have been selfed and two have been used in backcrosses. The most interesting and valuable seedlings have been obtained from this cross of Alexandria x Black Monukka.

Muscat Hamburg crosses:—Muscat Hamburg is a black variety. The normal berries are above medium in size, oval to roundish oval, and although the stamens are upright, frequently small, round, seedless berries occur in the normal clusters. The Muscat Hamburg has a distinct muscat flavor but is decidedly different in aroma from the Muscat of Alexandria. Black Monukka and Panariti were used as male seedless parents in crosses with Muscat Hamburg.

Twenty-nine seedlings were obtained from the Muscat Hamburg x Black Monukka cross, 22 of which have fruited. All vines had upright stamens. Four seedlings were white and 18 varied from dark red to purple black in color. The berries ranged in size from very small to medium large. While the fruit from all the vines was distinctly rich in flavor, the decided muscat flavor was apparent in only three of the seedlings. One very small fruited seedless seedling with a muscat flavor was obtained from this cross. Three other seedlings produced only rudimentary seeds. Two of the seedlings have been propagated for production records while eight seedlings have been selfed. Three of the seedlings have been used in backcrosses. The outstanding result of this cross was the production of a very small seedless, muscat flavored seedling. This seedling has been propagated for production trials and if production records are favorable it should have value as a commercial currant type raisin.

Nineteen seedlings were grown from the Muscat Hamburg x Panariti cross, all of which have fruited. All vines had upright stamens. Two seedlings were white while 17 varied from purple black to black. All the seedlings were small in size, 16 varied from slight to decided muscat flavor, and none were seedless. This cross did not yield any seedling of apparent value. Two seedlings were selfed however in order to study segregation of characters.

Black Monukka crosses:—In addition to the use of Black Monukka as a male parent in crosses with muscat flavored grape varieties, crosses have also been made between other varieties and Black Monukka for the production of seedless varieties. In some of the first crosses made in 1923, Gros Guillaume x Black Monukka produced one seedless seedling from nine plants grown. Rodites x Black Monukka produced one seedless seedling from one plant grown. From these indications of the value of Black Monukka as a male parent in seedless production, other crosses were made.

Twenty-four seedlings were grown from the Pizzutello (white) x Black Monukka cross, 19 of which have fruited. All seedlings had upright stamens. Three seedlings were white in color while 16 varied from light red to purple black. In size the seedlings varied from small to large. Three seedlings were seedless and three others had only rudimentary seeds. Pizzutello bears distinctly falcoid shaped berries. The seedlings varied from falcoid to pointed fusiform in shape. The three seedless seedlings have been propagated for production tests while some have been selfed and others used in backcrosses.

Forty-four seedlings were grown from the Damas rose x Black Monukka cross, 40 of which have fruited. The type of stamens in this cross was not ascertained. Nine seedlings were white in color while 35 varied from light red to purple black. Two seedlings were seedless while four others produced only rudimentary seeds. One seedling has been propagated for production records while three others have been used in backcrosses.

Two hundred seventy-five seedlings have been grown from the various crosses with the male parent a seedless variety, 85 per cent of these have fruited. Reflexed stamens occurred in 13.2 per cent of the seedlings fruiting although all parents had upright stamens. In the transmission of color white has been a pure color but recessive to black. In most cases black has been heterozygous. The red color has varied from light red to dark red in intensity. Twenty-nine seedless or practically seedless grapes have been produced, representing 12.4 per cent of the fruiting vines. The production of seedlessness in the F_1 generation has proven the practical value of using male seedless parents. The ratio of seedless or near seedless plants produced to seeded plants in the first generation would indicate that seedlessness is not a simple inheritable dominant factor. It is an interesting fact that no seedless plants were derived from crosses of the true seedless currant-type grapes, namely, Corinthe blanc, Corinthe Rose, and Panariti. While muscat flavor occurred in some seedlings Muscat Hamburg appeared to transmit the factor for muscat flavor to a greater degree than Muscat of Alexandria. In two seedlings however the muscat flavor and seedlessness have been produced. The seedless plants of intrinsic value as well as the seeded plants possessing commercial promise have been propagated for production records.

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Five Strains of the Scuppernong Variety of Muscadine Grapes

By J. G. Woodroof, *Tifton, Ga.*

THE Muscadine grape (*Vitis rotundifolia*) was doubtless the first native or American grape to attract the attention of the early settlers on the Carolina shores, and was the first to be brought into cultivation.

At a very early but unknown date a wild vine bearing light colored fruit of superior quality was found on the northeastern shore of North Carolina. New plants were obtained from this vine which were planted in the area nearby. At that time it was referred to as the "White grape", "Hickman grape" or "Roanoke grape". About 1810 it became known as "Scuppernong". For many decades it was the only cultivated variety of the species which produced light colored fruit, and for nearly 200 years has been the standard by which new varieties have been compared and judged.

It has been more extensively planted than all other varieties of the species combined. Just after the Civil War it was recommended and planted about thousands of homesteads in nine states throughout the South. While it has no one quality that other varieties do not have, possibly no other variety possesses any more good qualities and as few weaknesses. The grapes are borne in clusters of from three to 20 and shed off easily after becoming fully ripe. They range from one to 150 grapes per pound; have a bronze color with from 40 to 60 brown dots; russet splotches are usually, but not always present. They are sweet, sub-acid, free from either tart or musty flavor or aroma, and when eaten fresh from the vine are most pleasing.

Scuppernongs are grown chiefly around farm homes on arbors from a few square yards to one-eightieth of an acre; and many arbors now in existence are more than 100 years old.

During the 200 years that Scuppernongs have been known they have been propagated by thousands of individuals usually only a few plants at a time. Many variations have developed within the variety. Homesteaders are aware that the grapes on their vines are "late", "early", "sweet", "large", "clustered", or the like, but do not know the origin of the variation.

Husmann and Dearing (1) state that "there seem to be at least three strains" of Scuppernongs in cultivation. They found that two strains ripen in September and are large, sweet grapes while a third ripens in October and is sour. Stuckey (2) states that there is more than one strain of Scuppernongs.

After making detailed examinations of grapes from thousands of vines growing on several hundred homesteads in North Carolina, South Carolina, Georgia, and Florida, it was found that five variations could be grouped and considered as strains. These variations are in time of ripening, sweetness, size, color, tendency to shed, and number of grapes per cluster. While environmental conditions may influence some of these, they cannot account for vines of two or three strains occurring on one arbor within a few feet of one another. As

Scuppernongs are practically always propagated by layers, variations within the bud is suggested as the origin of the variations in fruiting habit of the vines. It is doubtful that they originated as seedlings because practically all home arbors are pollinized by native black male plants and the seedlings produce black fruit. Table I summarizes the characters of the five strains of Scuppernongs.

It is recommended that nurserymen propagate Scuppernongs by strains, and sugggested that vines of Strains 2, 3, and 5 be grown about the home to insure a long ripening season. In this way Scuppernongs may be had for the family from the arbor for 8 weeks, from early August to early October.

TABLE I—DESCRIPTION OF STRAINS OF SCUPPERNONGS

Character	Strain 1	Strain 2	Strain 3	Strain 4	Strain 5
Grapes per pound	100–110	110–120	120–130	130–150	130–150
Sweetness	Sweet	Very sweet	Very sweet	Slightly sour	Sweet
Flavor	High	Very High	Very High	High	High
Season	Early	Mid-season	Mid-season	Late	Late
Color	Light bronze	Light bronze	Bronze	Greenish-bronze	Reddish-bronze
Bloom	Very slight	Very slight	Slight	Present	Present
Dots	Conspicuous	Conspicuous	Very conspicuous	Submerged	Submerged
Thickness of hull	Medium	Thin	Thin	Medium	Thin
Grapes per cluster	3–6	3–8	3–10	4–12	4–12
Tendency to shed	Slight	Slight	Slight	Great	Slight
Desirability	Fourth best	Second best	Best	Poorest	Third best

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The Response of the Hunisa Grape to Girdling

By H. E. Jacob, *University of California, Davis, Calif.*

THE viticultural literature, beginning about the middle of the eighteenth century, contains many references to the girdling (ringing) of grape vines. The results generally have been stated as a better set and an increased size of the berries and a hastening of fruit maturity. Many investigators have published data to support their conclusions, but very few have made any attempt to differentiate between the nature and magnitude of the responses obtained in the berries containing well-developed seeds and in the seedless berries.

A paper (1) presented in 1928 briefly summarized some of the results obtained by girdling vines of certain of the seedless grape varieties. Since that time a number of varieties have been used that produce both seeded and seedless berries on the same clusters. Of these the Hunisa, a relatively little known table grape, has given the most striking and clear-cut responses. The seedless berries of this variety apparently develop parthenocarpically while in the seeded berries fertilization and seed development take place normally. The berries are, therefore, either completely seedless or contain one or more fully developed, hard seeds. This character makes the variety ideally suited to the purpose of showing the relative differences in the response to girdling of the seeded and the seedless berries.

In this work parts of the same vines were utilized for girdling at different stages of development and other parts left for checks. The treatments were replicated on 24 vines each year. In 1932 and 1933 the girdling was done at three stages of development: (a) Early in the spring as soon as most of the flower clusters were out, which was approximately 4 weeks before full bloom; (b) when from 10 per cent to 40 per cent of the flowers were open (this stage is referred to as approaching full bloom in the accompanying table and in the discussion following the table, since it was done within 2 or 3 days of full bloom); and (c) after the bloom was past and the berries had set. (This was between 10 days and 2 weeks after full bloom.) By the time of the third girdling the normal drop of berries that always follows blooming had taken place. In 1934 the girdling was done only after the berries had set. The part of each vine to be girdled at each stage of development and that to serve as the check were selected at the time of the earliest girdling of the season and labeled. The orientation of the several treatments on the vine was changed from vine to vine so as to equalize the effects of location and exposure. The operation of girdling consisted in the removal of a ring of bark 3/16 of an inch wide entirely around the member girdled, which on some vines was an arm and on others a fruit-cane. The wounds usually callused over between the fourth and sixth weeks after girdling. In 1932 the crop was thinned to one cluster per shoot, while in 1933 and 1934 the thinning was based on the results obtained in the previous year so that the expected average weight of fruit per shoot would be as nearly uniform as possible. All thinning was done early in the spring soon after the flower clusters had unfolded.

In recording the results which are summarized in the accompanying table and in all the calculations, the cluster has been taken as a unit. The number of clusters used for observation in a single treatment in any year varied from 61 to 118. The seeded and seedless berries of each cluster were counted and weighed. Then they were crushed and an hydrometer reading (Brix) made on the expressed juice. The number of seeded and seedless berries per cluster and the berry weights are summarized in the following table.

TABLE I—THE INFLUENCE OF GIRDLING ON THE SET AND SIZE OF SEEDED AND SEEDLESS BERRIES OF THE HUNISA GRAPE

Time of Girdling	Year	Number of Berries per Cluster		Weight of 100 Berries (Gms)	
		Seeded	Seedless	Seeded	Seedless
Check (not girdled)......	1932	94±4.8*	78± 7.4	452± 6.2	97±2.4
	1933	72±4.8	184±12.1	561± 7.6	96±2.2
	1934	56±2.7	166± 9.5	627± 9.2	103±3.1
4 weeks before full bloom	1932	90±6.0	149±15.4	456± 5.0	82±1.6
	1933	76±5.4	591±28.7	561± 7.5	122±2.9
Approaching full bloom...	1932	94±5.4	441±51.9	445± 5.9	99±1.9
	1933	66±4.1	625±35.1	609± 8.7	157±4.6
Berries set..............	1932	83±4.4	77± 6.2	480± 7.5	128±2.8
	1933	60±4.1	222±18.9	643±10.0	185±4.6
	1934	57±3.9	174± 7.7	704±10.3	186±3.9

*P.E. by Bessell's formula.

When the treatments of the same year are compared, the figures clearly show that the girdling had no influence on the set of seeded berries but did greatly increase the number of seedless berries in the two lots girdled before full bloom. The effect was greatest in the lots that were girdled when the vines were approaching full bloom. The increase in the set of seedless berries as a result of this girdling amounted to 460 per cent over the check lots in 1932 and 240 per cent in 1933. Girdling after the berries had set did not increase the number of berries per cluster over that of the check for the obvious reason that most of the berries that were going to drop off had done so prior to the girdling.

Girdling during and prior to bloom had little or no influence on the size of the seeded berries but that done after the berries had set increased their size (weight) over those of the check about 6 per cent in 1932, 14 per cent in 1933, and 11 per cent in 1934. The increase in 1932 is of questionable significance but those of 1933 and 1934, while still of too small a magnitude to be of practical importance, are statistically significant.

A much greater influence of the girdling on size is evident in the case of the seedless berries. The lots girdled after the berries had set produced seedless berries 32 per cent, 93 per cent, and 80 per cent larger than those from the checks, respectively, for the years 1932, 1933, and 1934. In 1933 the seedless berries from the lots gir-

dled before and during bloom were larger than those from the checks, but smaller than those from the lots girdled soon after the berries had set. In 1932 the lots girdled when the vines were approaching full bloom produced seedless berries of approximately the same size as the checks while the seedless berries from the lots girdled 4 weeks prior to full bloom were actually smaller than those from the checks.

The hydrometer sugar tests failed to indicate any hastening of maturity in any girdled lot over that of the check. The fruit from all treatments on a single vine was harvested the same day and in most cases where differences in maturity occurred the check lots were the ripest. These data, however, lack conclusiveness and are not presented.

Summary

Girdling, regardless of time of application, did not increase the number of seeded berries per cluster. The number of seedless berries in the lots girdled in bloom was markedly increased. Girdling done 4 weeks prior to full bloom increased the number of seedless berries less than girdling in bloom, and girdling after the berries had set did not increase the number of seedless berries appreciably, if at all. Girdling after the berries had set increased the size of the seeded berries only slightly but increased the size of the seedless berries very materially. No hastening of maturity occurred as a result of girdling.

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Winter Injury to Grape Seedlings[1]

By RICHARD WELLINGTON, *Experiment Station, Geneva, N. Y.*

THE winter of 1933–1934 was too severe to obtain fine distinctions between the hardiness of varieties and seedlings, and yet it differentiated the hardy from the unhardy and semihardy. On the night of December 29 the official temperature at the New York Agricultural Experiment Station was –21 degrees F, and on the night of February 9, –31 degrees F. February also experienced many other subzero nights, such as –11 degrees on the 6th, –16 on the 8th, and –18 on the 10th. These same temperatures probably did not occur in the Station vineyards, but nevertheless they indicate the approximate degree of cold. Abnormally sunshiny weather was also experienced during the month of February but this may not have been an important factor. Just when the injury occurred to the vines is not known, but a number of cuttings taken from semi-hardy seedlings between the two low points were winter-killed. The influence of previous yields, condition of the vines, and the exact number of buds killed are not considered.

In this report, 2748 seedlings of fruiting age are given consideration. One hundred and thirty-two crosses and 13 selfs are represented. Fifteen *Vitis vinifera,* 20 *V. labrusca-vinifera* varieties, and 35 seedlings of *V. labrusca-vinifera* derivation were used as parents. Some of the European varieties as Muscat Hamburg appeared nine times and others only once or a few times. In the *V. labrusca-vinifera* hybrids are included such varieties as Moore Early, Lucile, Fredonia, Portland, Ontario, Brighton, Iona, Brocton, Dutchess, Golden Muscat, Mills, and Keuka. Some of these hybrid varieties are largely *V. labrusca* in composition while others approach *V. vinifera* closely. Ontario, which has made an excellent parent, was used 35 times, Sheridan 15, Golden Muscat 12, Hubbard 11, Portland 9, Eclipse (Riehl's) 8, Moore Early 7, Keuka 7, Wayne 7, and the remainder from one to several times.

The 35 seedlings used as parents were derived from many varietal combinations. Some were first generation seedlings while others were second generation selections. In the table that is based solely upon species composition, the seedlings and the American varieties are considered as a unit. None of these seedlings may ever be named, but all of them possessed one or more noteworthy characters. Most of them were used comparatively few times. Beta and Clinton were the only *Vitis vulpina* representatives.

The vines that fruited in 1934 are recorded but in most cases the crop was light due to the loss of buds. Where fruit occurred, a portion of the top was alive except where a small cluster was produced by secondary flowers on a basal shoot.

A is used to denote no top injury; B, top alive but fruiting canes dead; C, killed to ground; D, dead; and W, weak. The intermediates between these classes are denoted by A– and B–. The weak were generally found in class C.

[1]Approved as Journal Paper No. 72.

TABLE I—EFFECTS OF WINTER INJURY ON GRAPE SEEDLINGS

	No. Crosses or Selfs	No. Vines	No. Fruited	Per cent Fruited	A	A—	B	B—	Per cent Not Killed to Ground	C	D	W
(*V. lab.* x *V. vin.*) x (*V. lab.* x *V. vin.*)	82	1476	94	6+	22	32	124	25	14—	1257	16	66
(*V. lab.* x *V. vin.*) x *V. vul.*	1	3	—	-	1	—	1	—	—	1	—	—
(*V. lab.* x *V. vin.*) x *V. vin.*	48	1038	1*	-	—	—	6	—	1—	1001	31	65
V. vul. x *V. vin.*	1	12	1*	-	—	—	—	—	—	12	—	—
(*V. lab.* x *V. vin.*) Selfed	13	219	5	2+	—	1	3	4	3+	206	5	61
Grand total	145	2748	101		23	33	134	29		2477	52	192

*Secondary bloom.

The data presented simply substantiate well known facts. It is difficult if not impossible to say just what percentage of a certain species a certain variety or seedling may possess. If a supposedly pure labrusca is crossed with a pure vinifera as in the case of Roger's hybrids, one might assume that the resultant seedlings are 50 per cent *Vitis vinifera.* Using this standard of measurement, many seedlings that are nearly 85 per cent *V. vinifera* have been considered sufficiently hardy to produce fruit annually when grown at Geneva. This past year all of the Roger's seedlings growing on the Station grounds were killed to the ground. Brighton, Delaware, Niagara, Diamond, and many other well known kinds fared no better. Labrusca types, as Concord, Cottage, Colerain, and Moore Early came through with a fair crop and slight injury. Vulpina types, as Elvira, Noah, and Marion were particularly hardy. Time and space do not warrant a discussion of the performance of the 145 crosses and selfs covered in this report. As might be expected, certain varieties imparted a higher degree of hardiness to their progeny than others. Outstanding crosses that escaped winter injury in part are Fredonia by Worden (a cross made by F. E. Gladwin) Ontario x Moore Early, Ontario x Station 9976, and Ontario by 9978 (the last two being Concord Seedless types used by A. B. Stout), and 8187 by 9976 (Stout's cross). Selfs of 10903 and 10905 also produced hardy progeny. Sta. 8187 was obtained from a cross between Vergennes and Hubbard Seedless (a Concord Seedless type) and 10903 and 10905 from a cross between (Delaware x Goff) and Concord Seedless. Since Ontario did not transmit hardiness to most of its crosses and its selfs, Moore Early and Concord Seedless must be largely responsible for the hardy

seedlings in these crosses. The performance of other Concord Seedless crosses as also the selfs from 10903 and 10905 that contain Concord Seedless characters corroborates this statement.

According to Gladwin the Worden is hardier than the Concord and the Concord is slightly hardier than the Fredonia. Since Fredonia in three crosses did not transmit hardiness, Worden should probably be given the chief credit in transmitting hardiness in this cross. Seedlings derived from selfs are generally weak, and this fact is substantiated in this report, for the selfs gave proportionately 10 times as many weak plants as the hybrid crosses.

As already noted, many of the fine distinctions in winter hardiness of the grape were obliterated by the intense cold, but since winters like that of 1933 to 1934 are infrequent, it was thought that even the minor differences should be recorded. Not enough *Vitis vulpina* crosses were used to say anything about their hardiness, but judging from the cold resistance of many varieties that are largely *V. vulpina* in composition, it is obvious that this species should not be overlooked in breeding hardy grapes. *V. labrusca,* as is well known, is much hardier than *V. vinifera* and the performance of the seedlings noted emphasize this fact. For extreme hardiness a combination of the *V. vulpina* and *V. labrusca* types should prove excellent.

A Study of Production and Physiology of Concord Grape Vines as Affected by Variations in the Severity of Pruning[1]

By T. J. MANEY and H. H. PLAGGE, *Iowa State College, Ames, Ia.*

THE investigational work in grape pruning which has been carried on during the past 15 or 20 years has developed a rather extensive literature, particularly in respect to work which has dealt with studies on the fruiting habits of various buds on fruiting canes as affected by the type and degree of pruning. The brevity of this paper makes it impossible to review the literature with any degree of completeness. Consequently, reference is made to the report of Schrader (1), in which the field has been quite thoroughly covered.

MATERIALS AND METHODS

The account on grape pruning herewith presented deals mainly with some studies in which 10 lots of approximately 10 mature vines each of Concord were pruned on the basis of leaving 40 buds per vine. Lot 1 was pruned to 40, 1-bud spurs; lot 2, to 20, 2-bud spurs; and so on up to lot 10 on which were left 4 10-bud canes. In lot 1 it was observed that at the juncture of the fruiting cane with the older wood there was invariably a rather undeveloped basal bud. Therefore, in this lot five vines were pruned of fruiting wood back to this bud, and six vines were pruned so as to include this bud and the first normally developed bud located at the first distinct node.

In addition to the preceding lots, one lot of six vines was pruned so as to leave each vine with four canes of 25 to 30 buds each, thus giving a bearing surface approximately three times greater than the vines in the other 10 lots.

For the purpose of the experiment uniformly vigorous 6-year-old vines were selected from among 180 vines which were growing in six adjacent rows. The vines had been trained according to the single stem two-wire Kniffen system. The soil on which the vines were growing was a very heavy rich black loam and the lay of the land was practically level. The vines had a fair crop in 1930 which was not recorded. In 1931, the first year of the experiment, the blossoms were severely injured by a late frost. The crop in 1932 was heavy. In 1933 another spring frost caught the blossoms, while in 1934 a very heavy bloom was severely injured by the extreme heat and drouth which prevailed at blossom time. In all years there was a sufficient show of bloom to have developed an apparently normal crop.

The pruning studies were carried out during the seasons of 1931, 1932, 1933, and 1934. Pruning was done each year in early spring just before bleeding or bud swelling commenced. The exact dates of pruning were as follows: 1931, April 16; 1932, March 28; 1933, March 30; 1934, March 18.

[1]Journal Paper No. J-238 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 289.

In connection with the work on this project it was only possible to devote a relatively small amount of time to chemical analyses, although it is recognized that it would have been highly desirable to have had a seasonal record of the chemical activity of the vines. In view of the fact that Snyder (2) found that the most active period in the subdivision of the differentiated clusters occurred early in the spring at the time of bud swelling, it was decided to confine all the work to an analysis of the samples taken at the time of the regular pruning operations.

At the time of pruning, samples of the fruiting canes were taken from vines in each lot for chemical analyses. In the preparation of the samples about 2 inches of the nodal portions of the canes were selected. For added comparisons composite samples of trunks and roots were taken. In 1931 these samples were obtained from extra vines handled along with the various lots, while in 1932 and 1933 they came from extra plants in the 1- and 10-bud lots.

The nodal samples of the wood, together with the samples of roots and trunk, were taken immediately to the laboratory, where they were cut into very small pieces and processed in hot alcohol. Determinations of reducing, non-reducing and total sugars, together with colloidal, non-colloidal and total nitrogen were made. The extraction of sugars and soluble nitrogen was by decantation. The Bertrand modification of the Munson-Walker method was used in estimating reducing and total sugars. Nitrogen analyses were carried out by the official Kjeldahl method.

Results

In the tabular data which follows, the production data in Table I are condensed to averages for the 4 years of the experiment. Tables II and III set forth the data obtained from the various chemical analyses performed.

TABLE I—Production of Pruned Concord Grape Vines

Type of Pruning	No. of Vines	Total Yield (Pounds)				Total Yield (Pounds) 1931–1934	Av. Yield per Vine per Year (Pounds) 1931–1934
		1931	1932	1933	1934		
40, 1-bud spurs,, basal bud......	5	4.0	33.0	14.5	21.0	72.5	3.6
40, 1-bud spurs, first normal bud	6	2.5	65.5	24.0	25.2	117.2	4.8
20, 2-bud spurs...	10	21.7	243.0	45.0	74.5	384.2	9.6
14, 3-bud spurs...	10	21.0	202.0	48.5	68.7	340.2	8.5
10, 4-bud spurs...	9	31.2	153.0	55.5	77.2	317.0	8.8
8, 5-bud canes....	10	9.0	154.0	73.0	80.7	317.2	7.9
7, 6-bud canes....	10	22.5	215.0	73.0	86.5	397.0	9.9
6, 7-bud canes....	10	18.7	229.5	96.5	135.2	480.0	12.0
5, 8-bud canes....	10	20.7	226.0	71.5	138.0	456.2	11.4
4½, 9-bud canes..	10	15.0	218.5	71.5	107.5	412.5	10.3
4, 10-bud canes...	10	18.5	214.0	82.5	108.0	423.0	10.5
4, 25–30-bud canes	5	—	268.7	110.0	151.0	529.7	35.3

TABLE II—PERCENTAGE OF SOLUBLE CARBOHYDRATES IN DORMANT BUDS AND WOOD. (PERCENTAGE ON GREEN WEIGHT BASIS)

Description of Sample	Reducing Sugars			Non-reducing Sugars			Total Sugars		
	1931	1932	1933	1931	1932	1933	1931	1932	1933
40, 1-bud spurs, basal bud	1.65	3.04	1.58	0.59	1.57	3.08	2.24	4.61	4.66
40, 1-bud spurs, first normal bud	1.70	3.35	1.68	0.73	1.38	2.76	2.43	4.73	4.44
20, 2-bud spurs	1.90	3.33	1.79	0.18	1.07	3.23	2.08	4.40	5.02
14, 3-bud spurs	1.98	3.28	1.67	0.31	1.73	2.95	2.29	5.01	4.63
10, 4-bud spurs	1.95	3.31	1.62	0.13	1.17	3.03	2.08	4.48	4.65
8, 5-bud canes	1.82	3.43	—	0.26	1.30	—	2.08	4.73	—
7, 6-bud canes	1.98	3.60	1.53	0.05	1.10	2.96	2.03	4.70	4.49
6, 7-bud canes	1.76	3.85	—	0.22	0.79	—	1.98	4.04	—
5, 8-bud canes	1.88	3.87	1.54	0.19	—	2.91	2.07	—	4.45
4½ 9-bud canes	1.95	3.04	—	0.20	1.73	—	2.15	4.77	—
4, 10-bud canes	1.95	3.96	1.53	0.19	1.14	3.22	2.14	5.10	4.75
4, 25-30-bud canes	—	3.54	1.75	—	1.39	3.43	—	4.93	5.18
Roots	0.64	0.44	0.82	1.29	1.70	2.67	1.93	2.10	2.33
Trunk	1.60	2.40	1.48	0.61	2.05	3.06	2.21	4.45	4.54

TABLE III—NITROGEN CONTENT OF DORMANT GRAPE BUDS AND WOOD. (MG. PER 100 GR. GREEN TISSUE)

Description of Sample	Non-colloidal Nitrogen			Colloidal Nitrogen			Total Nitrogen		
	1931	1932	1933	1931	1932	1933	1931	1932	1933
40, 1-bud spurs, basal bud	38.7	68.9	43.6	264.6	487.0	320.6	303.3	455.9	364.2
40, 1-bud spurs first normal bud	42.1	71.6	43.3	273.8	401.9	321.4	315.9	473.6	364.7
20, 2-bud spurs	40.9	81.2	38.4	278.0	416.7	311.6	318.9	497.9	350.0
14, 3-bud spurs	39.2	58.9	38.4	280.0	390.2	310.5	319.2	449.1	348.9
10, 4-bud spurs	40.0	70.6	47.4	266.4	395.9	304.4	306.4	466.6	351.8
8, 5-bud canes	38.9	71.5	—	270.0	404.8	—	308.9	476.3	—
7, 6-bud canes	41.5	76.1	48.8	293.0	426.6	306.0	334.5	502.7	354.8
6, 7-bud canes	44.0	68.2	—	264.4	405.8	—	308.4	474.0	—
5, 8-bud canes	41.5	52.2	47.6	278.2	377.8	336.0	309.7	430.0	383.6
4½, 9-bud canes	42.9	75.1	—	285.0	405.3	—	327.9	480.4	—
4, 10-bud canes	44.7	62.6	49.3	277.0	414.0	326.0	321.7	476.7	375.3
4, 25–30-bud canes	—	63.4	41.1	—	403.4	350.4	—	466.8	391.5
Roots	190.0	183.2	256.6	454.0	552.6	568.0	644.0	735.8	826.1
Trunk	48.4	83.4	53.4	234.0	357.8	255.8	282.4	469.2	309.2

DISCUSSION

From the production records in Table I, in so far as the average yield per vine per year for the 4-year period is concerned, it is apparent that very low production is associated only with the basal and first buds on the fruiting canes. General investigational work has shown that the first three buds are relatively low in production. The surprising fact is the high production of the 2-bud spurs for the full crop year of 1932. In this instance the 243 pounds yield was high for all the 40-bud lots. Buds 2 to 6 average fairly close in annual pro-

duction per vine and then there is a noticeable increase on buds 7 to 10. However, the data show that good average production is possible from all but the first buds on the vines pruned in the manner outlined. In this respect the data bear out the experiences of Wiggans (4) and Swartwout (3). The latter found considerable fruit development from adventitious buds when all fruiting canes had been removed.

Of particular interest is the total production of the vines with four 25- to 30-bud canes, whose average production is three times greater than the best of the lots in the other treatments. These long pruned vines maintained their vigor notwithstanding the heavy production. The behavior of these plants suggests that when dealing with Concord grape vines growing on rich heavy soil fewer plants might be planted, and that the amount of fruiting wood on these could be materially extended. It is also of interest to note that the weights of prunings removed from the individual vines in the various lots never varied more than 2 pounds between the extremes, the high being 6¾ pounds on the 4-bud lot and the low 4¾ pounds on the 1 to 3 and 7-bud lots.

In connection with this experiment detailed records were made on the fruit production at the different nodes. With the longer canes, 8 to 10 buds, the peak of production was generally between buds 4 and 7, inclusive. On canes of this length the three basal buds were generally very low in production. When pruning was carried to the extreme, using 25- to 30-bud canes, frequently the first five or six buds on the cane were unfruitful. This suggests that the development of the basal buds on the cane is dependent on length and number of buds on the fruiting cane. The production on these long canes was pretty well distributed on all buds from 7 to 30. In many instances the buds at the extremities of the canes were the highest in production. Since the main development of the differentiated clusters takes place only shortly before blooming, there may be competition for the stored food reserves, and the buds farther out on the cane may be most successful in utilizing the storage materials. When the canes are spurred back, then the basal buds have a chance for greater development in number and size of clusters.

The data for the chemical analyses are outstanding in that they are non-revealing in respect to any of the wide differences in production which occurred between the most extreme treatments. The values for the samples from the different lots are so strikingly similar that they permit of no deductions which might correlate chemical composition with differences in fruitfulness. With reducing sugars, colloidal and non-colloidal nitrogen, except in roots, there is a build up in the off year and depletion in the on year. With non-reducing sugars there is a progressive build up irrespective of the amount of fruit production.

Conclusions

It is recognized that the results of this study are too meager to be very conclusive. The data suggest that the basal buds on a cane are not unproductive just because of their position alone, but that their development and production may be influenced by their competition

for food reserves with other buds farther out on the cane in long pruned canes. The high production of the vines pruned to extremely long canes suggests that under certain conditions perhaps some attention should be given to the possibility of reducing the number of vines per acre and increasing the amount of fruiting wood.

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Inheritance of Gooseberry Leaf Infection

By A. S. Colby, *University of Illinois, Urbana, Ill.*

IN connection with the gooseberry breeding work in progress at the Illinois Agricultural Experiment Station, studies are being made of the relative value of certain varieties as parents. In a previous report (1) having to do with the transmission of size factors in nine gooseberry varieties selfed and crossed, it was shown that of the varieties used, Poorman carried the largest number of factors for large berry size. This report has to do with the comparative resistance to the common leaf diseases (anthracnose and leaf spot) shown by the same seedlings discussed in (1) with the addition of 501 other seedlings divided among the various groups, a total of 1301 individuals.

It is generally recognized that defoliation by the common leaf diseases as early as mid-summer is detrimental to the plant. While a well-arranged spray program usually prevents defoliation, varieties which retain their foliage throughout the season without having been sprayed are much to be desired, especially if they possess other good horticultural characteristics.

In this project, the seedling plants were grown under similar field conditions in fertile, well drained soil and handled as nearly alike as possible. No sprays were applied. Records of comparative infection to leaf diseases were taken twice each season, in June and September, over a period of 4 years, 1930 to 1933.

The plants were at least 2 years old when the records were started. The following arbitrary standard for comparative infection was used, namely, (a) light, up to 10 infected leaves on a plant with up to 10 diseased areas on each leaf; (b) medium, up to 50 infected leaves on a plant with up to 20 per cent of those leaves half covered with the spots; and (c) heavy, more than 50 leaves infected, often so seriously that defoliation resulted.

Fig. 1 shows the value of the varieties used as measured by the relative resistance of leaf diseases in the seedlings. Percentages of leaf infection rated as light, medium, and heavy are given for the progenies of each of the nine crosses and selfs. It is evident that in most of the progenies studied there is a partial absence of factors for resistance to the common gooseberry leaf spots. However the fact that 30 per cent of the crosses between Transparent and Rideau and 31.5 per cent of the self-pollinated seedlings of Como show only light infection, indicates that these varieties carry factors for resistance. In most cases, when Carrie was used as a parent, it appeared to have some value in introducing the high resistance factor. Poorman, Glenndale, Oregon Champion, Downing, and Minnesota No. 96, when either crossed or selfed appear the least promising as parents in introducing those factors which result in a high degree of resistance to the leaf spots. The wide variations in resistance found may be attributed to differences in the genetic constitution of the several varieties and suggest that multiple factors for resistance are concerned.

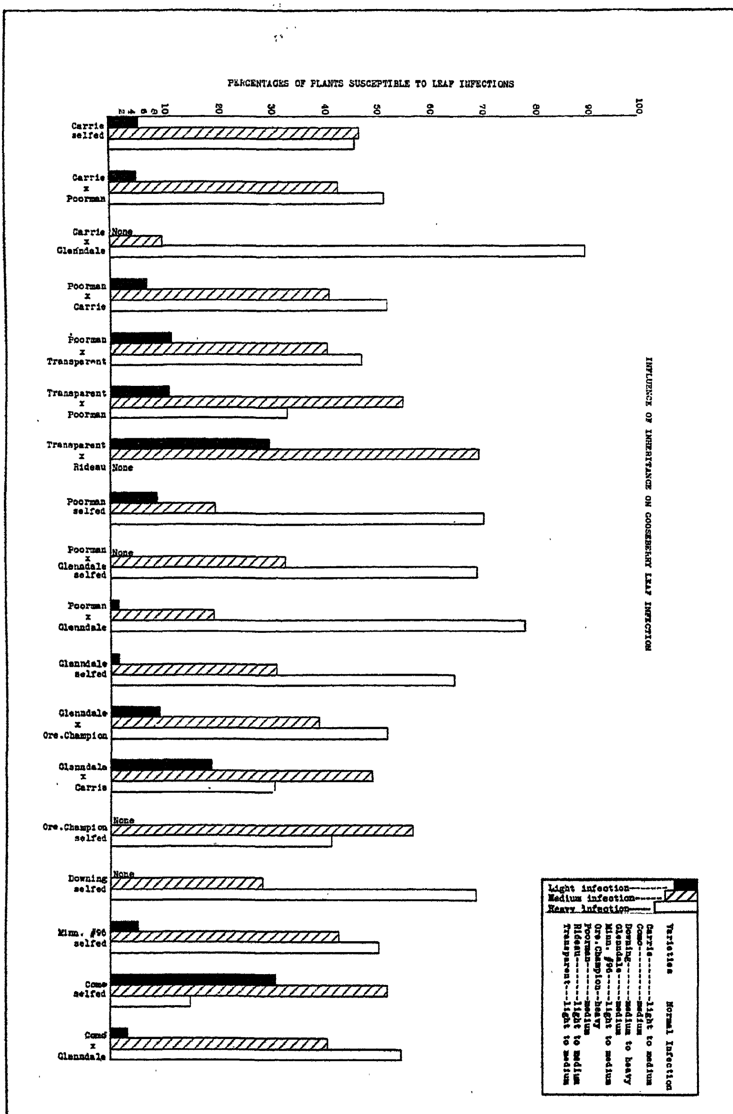

FIG. 1. Relative resistance to leaf infections on 1301 seedlings resulting from crossing and selfing nine gooseberry varieties. The results are based upon percentages of plants with light, medium, and heavy infection.

Considering the numbers of seedlings involved, there were no significant differences in the resistance to the leaf spotting diseases in the reciprocal crosses where Poorman, Carrie, Glenndale, and Transparent were used as either the pistillate or staminate parent.

The results of this work indicate that, of the varieties used, Transparent carried the largest number of factors for resistance to leaf spotting infections. This variety, therefore, appears a desirable one in a breeding program where resistance to such diseases is sought. However, several seedlings in each of several groups were found which were high in disease resistance and of value from the standpoint of both spinelessness and the production of large fruit, other characteristics being sought in this project.

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Fertilization of Red Raspberries

Progress Report

By A. E. STENE, *Rhode Island State College, Kingston, R. I.*

LAST year the writer presented a paper before this society (1) summarizing the results of two experiments on fertilization of red raspberries. The second experiment was regarded as incomplete, and records of an additional comparable crop should help to determine the significance of previous yields. On the site of this experiment, raspberry plants (Latham variety) suffered little if any from the unusually low temperature of the 1933–34 winter, and started the season normally. A protracted drought during July reduced the yield somewhat as compared with the previous season. Table I summarizes the yields for 1934 as compared with 1933.

TABLE I—AVERAGE YIELD PER PLAT IN KILOGRAMS OF LATHAM RED RASPBERRY WITH VARIOUS FERTILIZER TREATMENTS

	500 Pounds per Acre		1000 Pounds per Acre		1500 Pounds per Acre	
	1933	1934	1933	1934	1933	1934
No fertilizer	16.7±1.40	8.5±0.53	9.7±1.0	7.8±0.79	11.4±1.0	7.6±0.85
No K....	19.9±1.67	13.9±0.87	17.4±1.7	7.2±0.73	17.7±1.5	8.9±1.0
No N....	25.2±2.12	16.3±1.02	25.3±2.5	13.9±1.41	19.0±1.7	9.9±1.11
No P_2O_5	26.2±2.12	24.8±1.55	28.0±2.8	26.6±2.69	31.2±2.7	15.7±1.76
Complete	32.4±2.72	25.1±1.57	35.6±3.5	27.1±2.74	33.3±2.9	19.2±2.15

The general trend of average yields follows that of last year. Lack of corresponding response from heavier applications of fertilizer is greater even than last year.

On the other hand, the reduction in yield due to the drought seemed to relate iself in some degree to the previously indicated need for the fertility elements in that the greatest reduction occurred where no potash was used and the next largest where nitrogen was omitted.

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A Study of the Morphological Changes and the Origin of Roots in Tip-layered Cumberland Raspberry Plants[1]

By R. H. SUDDS, *Pennsylvania State College, State College, Pa.*

ALTHOUGH the commercial cultivation of the black raspberry dates from the artificial adaptation of tip layering, and while the natural tip layering of the black raspberry has been observed for an even longer period, accurate descriptions of it are lacking and anatomical and morphological studies are not recorded. This paper gives in part the results of such studies; in it are outlined the gross morphological and anatomical changes accompanying tip layering. The points of origin of root primordia are particularly pointed out.

In nature the first year canes of the black raspberry droop with continued elongation and eventually their tips may touch the ground, frequently developing roots; if their movement and consequent injury is prevented the roots may become established. Plants volunteering in this way are seldom satisfactory; more desirable ones are secured by inserting the tips of the canes vertically into the soil.

This is done when the tips have a peculiar appearance caused chiefly by the development of much reduced, recurved leaves on the later growth. Other external signs often suggested as indicators of the proper time to tip layer black raspberries, such as a reddening of the canes or the acquisition of a club-like appearance, are not essential. In this study, the latter character was observed only in the tips which were attempting to self-layer in consequence of contacting the soil or some other object. Contrary to some statements, leaves appear at all nodes.

After the rapidly elongating tip is layered, rooting has been observed within 3 days in tips which had not touched any object previously. As a rule, the younger internodes remain short. Axillary buds and cataphylls are present at definite nodes.

Under the conditions of this experiment, average tips commonly rooted in an intensive zone of from 12 to 18 nodes, with successive internodes beyond the rooting zone still being short. Several older nodes adjacent to this area frequently rooted, also. A recurving of the tip eventually resulted and it then grew vertically towards the soil surface. It is an interesting cause for speculation why the strong negative geotropism shows here only after rooting, when the unrooted tip does not show this phenomenon while growing procumbent nor when hanging perpendicularly in an inverted position. Some see in this natural method of propagation of the black raspberry the trend of evolution in certain higher plants for the stem to retreat below the ground.

Tips layered too early in the season rooted, then frequently grew out of the soil. Self-layered canes produced more variable plants than the articial method but the morphological and anatomical changes were basically the same. Subsequent to rooting, the root zone of the

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layered tips increased considerably in diameter over that of the cane terminals at the time of layering. This enlargement gradually decreased from the root zone of the tip plant towards the base of the parent cane; it was caused chiefly by an increased amount of secondary conducting tissue, especially xylem, and to a lesser extent by a greater amount of pith laid down in the cane grown after layering. Some of the diameter increment was also due to the roots crowding and uplifting areas of cortex and epidermis, as well as to their own bulk.

The endodermis of the roots stained a brilliant blue with a crystal violet-erythrosin combination and a deeper red with safranin alone and was easily traced in the case of the adventitious roots to the exact cells where it joined with the corresponding tissue of the stem which did not take the stain as deeply. A pericylic periderm developed early in the parent cane and tip, advancing progressively from older to younger regions. Pericyclic fibers followed the same course of development, but are not such a conspicuous part of the layered as of the above ground parts of the cane.

When a considerable length of a first year cane was layered horizontally, some of the older nodes rooted but the older the node the less the tendency to root. Mature nodes layered in late autumn seldom rooted until growth was resumed in the spring and then the roots came from the forcing axillary buds and rarely from the cane itself.

Continuing the external examination of the rooted tips, some nodes were found to possess roots at points in addition to those three already noted. Now and then on vigorous tips, roots were found on the cane about the axillary bud, on either flank or above it, as shown in Fig. 1, Nos. 3 and 4. Furthermore, when the terminal bud was injured or broken off or when the canes were very vigorous, the axillary buds were frequently forced into growth and these often rooted at the nodes in a manner analogous to that of the nodes of the parent cane, as shown in Fig. 1.

Even a casual examination of the rooted tips showed that the roots were located at certain definite points. Priestley and Swingle (4) cite Beijerinck's (1) statement that when root initials are present or can be induced experimentally, they are usually distributed around a leaf insertion, sometimes in a leaf axil but more frequently to either side of it and a little below it, is borne out by the position of the roots in the tip-layered black raspberry node as shown in Fig. 1. All of these variations were found, with the usual situation being one root below each side of the upper points of attachment of the petiole with the stem and a single pair of roots below the center line of the petiole, as in Fig. 1. The numbers of roots at any one of these three points on a rooting node occasionally varied from none to three.

In order to determine the approximate proportion of roots, 169 rooted Cumberland nodes were examined under a wide angle microscope. One hundred and thirty-eight nodes showed the usual pair of roots at Fig. 1, No. 1, and 125 had the customary single root at Fig. 1, No. 2, while in 18 cases roots appeared about the axillary bud on the cane as in Fig. 1, Nos. 3 and 4. Other variations were found, but more infrequently. This root distribution may vary with the variety

or other factors. One seedling black raspberry has produced a much larger proportion of roots at positions corresponding to Fig. 1, Nos. 3 and 4.

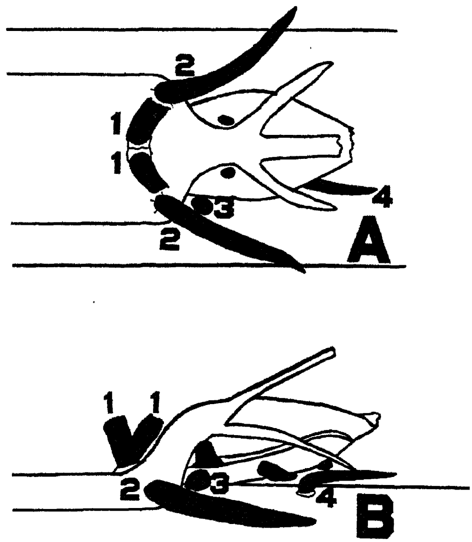

FIG. 1. Diagrammatic sketches of vigorous rooted nodes of the Cumberland raspberry. All roots solid black. (A) Top view. (B) Lateral view.
(1) Roots on median leaf trace, twins usual at each node.
(2) Roots on lateral traces, one single root usual on each lateral trace at each node.
(3) Root on branch trace.
(4) Root on stem above branch gap.
Unnumbered roots are on forced axillary buds. The leaf blades, part of the petioles, and most of the median roots have been removed.

Tips just rooting were selected for most of the studies of the sources of root origin because of their smaller size, greater ease in sectioning, and lesser amount of difficulty in interpretation of the sources of root origin with primordia or young roots present instead of mature roots. These were fixed in the standard formaldehyde-acetic acid-alcohol solution, treated with hydrofluoric acid, dehydrated through ethyl alcohol, cleared in xylol, then embedded in the rubber-beeswax-paraffin mixture described by Hance (2), and sectioned at thicknesses ranging from 20 to 24 microns, mostly with a sliding microtome. The sections were stained with several stains; a crystal violet-erythrosin combination gave good results as a differential stain.

As Woodcock (5) stated, there are three traces in the vascular supply of each leaf of the black raspberry; one is a larger median trace and two are equal sized smaller lateral traces. The four root primordia which usually form the roots at each node originate on the flanks of the leaf traces; the pair at the base of the center line of the petiole arise one on either flank of the median trace, Fig. 2, Nos. 1 and 4, and the two laterals originate one on the flanks of each lateral leaf trace, Fig. 2, Nos. 2 and 4. The primordia on the lateral traces develop either on the flank towards the median trace, Fig. 2, No. 4, or at an approximately 180-degree angle from it, Fig. 2, No. 2. Both these single lateral primordia at any given node appear in the same relative position. All these primordia were also connected with the procambial ring of the very young terminal or axillary bud or with the vascular cylinder in the somewhat older regions of the

canes. These root initials originated either before or after the three leaf traces "left" the procambial ring or vascular cylinder for the cortex, altho more often the latter was the case, especially in the youngest zone of the tips. Primordia were frequently found in the growing points of the terminal buds within one millimeter of the apex.

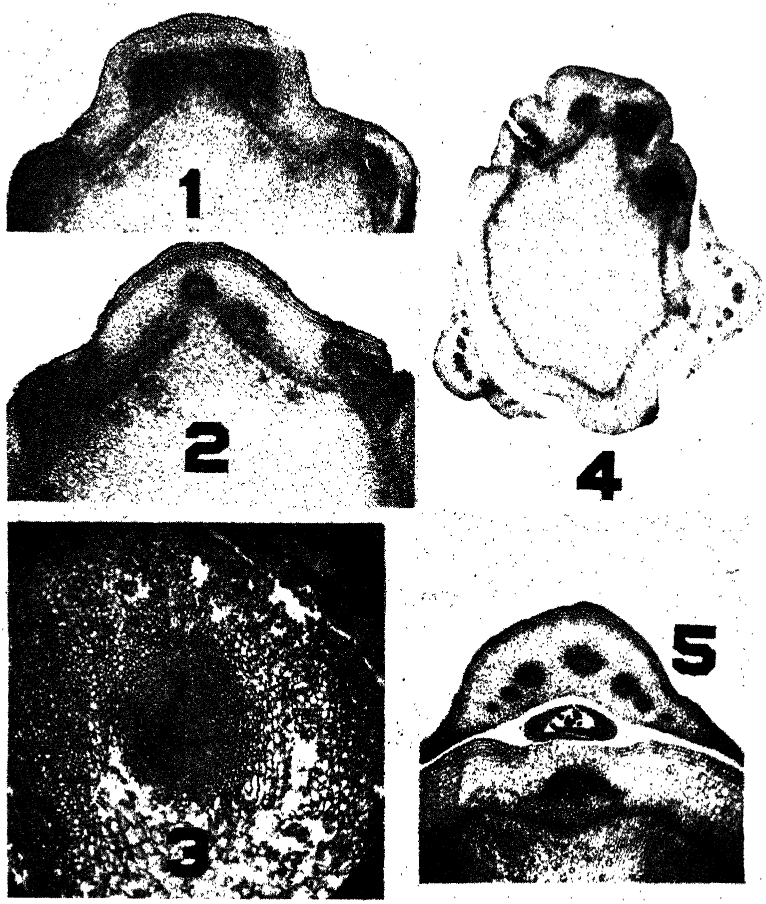

FIG. 2. Photomicrographs of transverse sections of Cumberland raspberry tip layers.

(1) Twin root primordia on median leaf trace; single primordia on lateral traces.
(2) Section median of lateral primordia, slightly higher than No. 1.
(3) Root primordium in pith of rooting axillary bud.
(4) Section in very young tip layer. Note position of lateral primordia as compared with No. 2.
(5) Root primordium on vascular cylinder of stem above branch gap.

The roots on the stem about the axillary bud originated from the branch traces, not shown in the figures, or from the vascular cylinder of the cane above the branch gap at strongly rooted nodes, as in Fig. 1, No. 4, and Fig. 2, No. 5.

There was no essential difference in the rooting of the terminal and axillary buds for the latter which rooted when forced into growth as shown in Fig. 1, did so in a manner analogous to the rooting of the primary axis. However, several unusual variations in the places of origin of the root primordia were present in the axillary buds.

The well developed root primordium in Fig. 2, No. 3, was found in the parenchyma cells in the pith of an axillary bud which was at the same time rooting normally from the leaf traces. This initial arose some distance inside the vascular cylinder and was in the process of being connected to it by newly forming vascular strands which were also differentiating from immature parenchyma cells.

Two young primordia, not shown in the figures, were located on the flanks of the median leaf trace in the base of a leaf petiole on a rooted axillary bud. Both of these were developing towards the adaxial side of the petiole.

Occasionally the ordinarily inconspicuous superposed accessory bud which is located between the base of the axillary bud and the petiole rooted feebly on forcing. A few primordia were located on the branch traces of the accessory buds.

Root primordia were sometimes found some distance back of the terminal bud, in the same transverse sections showing mature roots; in the majority of the transverse sections, especially in the tip, all the primordia were of about the same age.

One primordium arising in the stem from the flank of a lateral leaf trace was observed to be directed towards the pith of the cane rather than outwards through the cortex. This is not shown in the figures.

Root tips were often located exteriorly with the naked eye by means of the marked protuberances or swellings they caused as they grew in size and began to push outwards through the cortex, collenchyma, and epidermis even before any rupture was occasioned. This would indicate that in this case it is the pressure exerted by the growing roots rather than a digestive process which causes the pronounced bulge.

It was impossible in the great majority of cases to assign the origin of the root primordia resulting from the tip layering of the black raspberry to any cell or group of cells in any particular tissue, for the primordia were first distinguishable only a millimeter or so back of the growing point apex in the terminal bud as roughly hemispherical groups of cells on the flanks of leaf traces. At this time, the cells were the same in the most of the leaf trace, procambial ring, and primordium, as all possessed large nuclei and very deeply staining cell contents. Although the leaf traces were the first part of the vascular system to differentiate in any particular transverse section, this was evident at first chiefly by the appearance of a few tracheids. It was not until very young primordia were found on comparatively well differentiated leaf traces that the primordia appeared to origi-

nate in the pericycle. However, as has already been pointed out, at least the primordium found in the pith parenchyma, Fig. 2, No. 3, did not arise in the pericycle nor even close to any vascular tissue. The two primordia in the petiole both arose from the median leaf trace; one was situated on one flank of the cambium, while the other was located at a point well under the protoxylem area. The condition of the petiole made it impossible to make a positive identification of the tissue of origin.

Regardless of where the primordia were found, the point to be emphasized is that they were always in groups of cells which either had never ceased dividing or else were capable of resuming division when conditions were favorable. Even when a primordium seemed to arise in a particular tissue, other cells than those in which it originated contributed to its formation before the primordium showed any signs of rupturing the tissue in the neighboring cells about the root cap.

While the primordia were increasing in size due to a rapid division with but little individual enlargement of cells already a part of it, the adjacent parenchyma cells usually exhibited signs of division, resulting in additions to the primordia. The pith primordium was located in a spherical mass of dividing semi-meristematic cells smaller in size than the pith parenchyma from which they came and yet quite different from the truly meristematic cells in the primordium itself in that they did not possess such large nuclei and their cell contents did not stain so deeply.

The root primordia, once formed, rapidly differentiated into definite tissues; the root cap was the first distinguishable part, developing in the cortex before the root emerged. Root hairs appeared very soon after the emergence of the parent roots from the cane and lateral roots developed shortly afterwards. No endodermal leaks were observed in the development of the latter as the endodermis of the parent and branch roots were continuous.

No "root germs" were found to be present before rooting with the technique used unless previously initiated in response to some external factor, although Van der Lek (3) requires them of most woody dicotyledons not possessing a special type of rooting correlated with stem structure.

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The Best Parents in Red Raspberry Breeding[1]

By George L. Slate, *Experiment Station, Geneva, N. Y.*

In this paper varieties of red raspberries are evaluated as parents in breeding work by comparing the percentages of promising seedlings selected from various populations for further testing. Thirty varieties have been used as parents in producing 7684 seedlings. Eighty crosses were made, of which 12 were reciprocal. Thirteen varieties were selfed to produce a total of 324 seedlings. The seedlings on which this study is based fruited between the years 1903 and 1931, most of them being produced since 1920.

In Fig. 1 are listed the varieties used as parents. The population raised is given as the denominator of the fraction, the number of seedlings selected for further testing being the numerator. The percentage of the population selected is shown at the right of the fraction. At the right side of the table is a summary of all crosses in which a variety appears as either a seed or pollen parent. Selfs are not included in the table and summary since they were so inferior that their inclusion would result in an unfair estimate of the possibilities of the selfed varieties as parents in crossing. The breeding value of a variety may be estimated much more satisfactorily by observing its effect in crossing.

Seed parents	Pollen parents: Lloyd George	Herbert	Newman	1928	Cuthbert	Newman-20	Donboro	1994	Marlboro	Owasco	1950	2585	Erskine Park	2298	June	Newburgh	Marldon	Latham	Count	Empire	Ohta	Syracuse	Viking	Superlative	Golden Drop	Ranere	Brighton	Summary of all crosses in which variety appears as a parent: Plants grown	Crosses made	% selected
Lloyd George		17/329 5.1	21/178 11.8								1/51 1.9			0/23 0		34/577 5.9							17/617 2.7					4208	16	4.6
Herbert							0/4 0				0/42 0			0/28 0	5/59 8.4		0/8 0			0/14 0								817	15	4.6
Newman	12/194 6.1	8/16 50			5/22 22.7								0/9 0						0/13 0									648	12	7.7
1928	11/468 2.3	0/14 0	1/60 1.6											0/63 0							2/72 2.7	0/12 0						712	8	1.9
Cuthbert						0/59 0	0/35 0	1/40 2.5																	0/10 0			235	7	4.2
Newman-20	17/184 9.2			0/10 0				1/199 0.5		2/130 1.5		0/109 0		1/51 1.9														751	7	2.8
Donboro					0/19 0													0/17 0										182	7	—
1994	9/268 3.3	4/173 2.3	1/78 1.2									1/83 1.2																882	7	2.0
Marlboro															30/271 11.1		0/19 0		0/11 0					0/18 0				492	5	4.4
Owasco	10/160 6.2			0/13 0				1/42 2.4				1/25 4.0																378	6	3.7
1950	13/180 7.2	0/28 0																										348	6	4.0
2585	18/[illegible] 3.4																											850	6	2.2
Erskine Park			0/15 0								0/33 0										0/16 0					0/25 0		113	6	—
2298	0/59 0																											291	6	0.3
June					3/8 37.3															2/21 9.5							5/31 16.1	208	5	11.9
Newburgh	16/360 4.4									0/8 0													13/[illegible] 2.0					1602	5	3.9
Marldon		0/16 0	0/16 0				0/16 0																					75	5	—
Latham			1/29 3.4		4/43 9.3		0/33 0																					122	4	4.1
Count							0/21 0																					60	4	—
Empire		3/28 10.7																										63	3	7.9
Ohta	2/[illegible] 4.0										0/13 0																	134	3	3.0
Syracuse												1/57 1.7		0/17 0														86	3	1.1
Viking																0/16 0												1274	3	2.3
1934		0/10 0																							0/136 0			146	2	—
Superlative									0/21 0																			39	2	—
Loudon									12/342 3.5																			342	1	3.5
Buckeye												0/115 0																115	1	—

Fig. 1. The denominator of the fraction is the number of seedlings raised, the numerator the number selected for further testing, and the number at the right of the fraction is the percentage selected.

Parentage of numbered seedlings: 1928 (Empire x Herbert), 1934 (Empire x Herbert), 1950 (Empire x Herbert), 1994 (June x Empire), 2298 (June x *Rubus idaeus*), and 2585 (Newman x Herbert).

The indebtedness of the writer to Richard Wellington of this Station, who made many of the crosses on which this paper is based, is hereby acknowledged.

[1]Approved as Journal Paper No. 75.

A further estimate of the value of a variety for breeding may be had from a consideration of its offspring which are named and introduced and which assume importance in the raspberry industry of a region.

The evaluation of the breeding value of different varieties by a comparison of the percentages of their promising seedlings is of necessity limited by the judgment of the persons making the selections. Over a period of years standards change as better varieties and seedlings appear. Seedlings considered promising in 1903 might not receive consideration in 1931. The personal likes and dislikes of those making the selections are not the same. Nevertheless, in spite of the faults of this method of evaluating parents the fact stands out that certain populations contain many seedlings of superior merit while other comparable populations may not have a single seedling worthy of a second test.

Lloyd George has proved to be one of the most valuable parents in red raspberry breeding. The most promising seedlings have been derived from combinations of Lloyd George with Newman and with Newburgh. The fruits of seedlings from the cross between Newman and Lloyd George and the reciprocal cross are generally large, a number exceeding each parent in size. In general the long conic shape and the small refined drupelets of Lloyd George predominate among the seedlings. The firmness and lighter color of Newman are also present in the fruits of many seedlings. Considerable hybrid vigor in the seedlings is evident, the canes being taller and stockier than those of either of the parents, Newman and Lloyd George. The cross between Lloyd George and Newburgh resulted in some seedlings with exceptionally large fruits, usually somewhat rounder than those from the Newman cross, and of brighter color than those of either parent. Lloyd George, being rather soft, does not combine well with soft fruited sorts like Herbert and Ohta, most of the seedlings resulting from such crosses being too soft to be of commercial value.

Of the 231 second test seedlings now growing in the Station breeding plats, 14 were designated as promising or moderately promising during the 1934 fruiting season. Lloyd George was one parent in each case. Newman was the other parent in three, Newburgh in eight and Sta. 1950 (Empire x Herbert) in three cases. Two of these which have been selected for naming possess both Lloyd George and Newman as parents.

Newman has proved to be nearly as good as Lloyd George in yielding valuable seedlings. The outstanding Newman crosses are those with Herbert, Lloyd George and Cuthbert. The cross between Newman and Herbert resulted in only 18 seedlings, nine of which were of more than average merit. The fruit of these was characterized by large size and firmness, while the plants were very productive. Newman is probably the best source of firmness yet appearing in the Station's raspberry breeding work. The characteristic mild, somewhat flat flavor of Newman appears in the fruit of many of its seedlings, as does its tendency to large drupelets and somewhat coarse appearance. The berries of Newman seedlings frequently adhere to the torus somewhat more tightly than is desirable, although

this trouble has not appeared in the cross with Lloyd George. The new Newburgh variety resulted from the cross betwewen Newman and Herbert.

Loudon was used in only one cross in the early raspberry breeding work at the station. Twelve seedlings in a population of 342 raised from a cross with Marlboro merited second test and four of these were later named. One of these four, June, has become an important early variety in New York State. Ontario, a selfed seedling of a Superlative x Loudon seedling, is also of some importance in this state. Moreover, Loudon has shown its value as a parent in the raspberry breeding work of the Minnesota Station, Latham resulting from a cross between King and Loudon, and Chief being a selfed seedling of Latham.

June and Marlboro have given fair results in breeding, but their chief value is in introducing earliness and a bright fruit color into a population.

Herbert has proved outstanding only in the cross with Newman. To obtain firm-fruited berries, Herbert must be crossed with firm-fruited varieties; otherwise soft-fruited seedlings are obtained.

Cuthbert, in general has not given many good seedlings, but it has not been used extensively enough to warrant definite conclusions. It transmits its high dessert as well as its canning quality. A limited number of tests and observations indicate that to obtain a good canning variety Cuthbert will be necessary as one parent. Cuthbert blood may also be necessary in developing varieties for freezing.

Seedlings of Viking resulting from crosses with Newburgh and with Lloyd George are not as large fruited as is desired and the fruit does not hold up in size throughout the season. The berries are rather soft and the cavity so large that their shipping quality is poor. Latham has not been used sufficiently to determine its breeding value, but in crosses with Newman, Cuthbert, and Donboro, no outstanding seedlings resulted. In view of its resistance to mosaic and its wide adaptability to soils and climate Latham should be tried in further breeding operations, especially in developing varieties for regions where control of mosaic by the usual rogueing and isolation program is difficult—keeping in mind, of course, that the only true index of the desirability of a variety as a parent is the performance of its offspring.

Varieties that have not proved satisfactory as parents in the combinations tested are Erskine Park, Buckeye, Count, Donboro, Empire, Owasco, Syracuse, Gold Drop, Ohta, Ranere, Superlative, Newman No. 20, and Marldon.

A total of 334 individuals resulting from the selfing of 14 varieties and seedlings has been raised. Of this number only four seedlings, all of which resulted from selfing a Superlative x Loudon seedling, merited second test, and one of these was eventually named Ontario. Selfed populations are characterized by the presence of dwarfs, weaklings, a high proportion of individuals lacking hardiness and a considerable amount of partial and complete sterility.

The establishment of inbred lines has not been made a part of the raspberry breeding program of this Station because of (1) the long

time between generations, 5 to 6 years; (2) the high proportion of weaklings, dwarfs, and otherwise inferior individuals in a population; and (3) the difficulty of maintaining a number of inbred lines due to virus diseases, winter injury, and lack of vigor. Finally, the successful results already secured by cross breeding and the vast possibilities of improving raspberries by variety crosses make this method the most promising line of attack in red raspberry improvement at this Station.

Further Observations upon the Lloyd George Red Raspberry as a Parent in Breeding[1]

By C. D. SCHWARTZE, *State College of Washington, Pullman, Wash.*

THE breeding of hardy red raspberries as a means of solving the problem of winter injury of the Cuthbert variety in western Washington has been conducted since 1928 through the cooperation of the Washington Agricultural Experiment Station, Pullman, and the Western Washington Experiment Station, Puyallup. Acceptable new varieties must approximate Cuthbert in quality and flavor and in adaptability to commercial canning, freezing, and fresh shipment. A combination of high quality with hardiness is one of the most difficult of attainments in fruit breeding. Because of the advantage to be gained from a knowledge of inheritance in red raspberry crosses, data relative to certain fruit and plant characteristics are being recorded. From data published previously (1) it was concluded that the Lloyd George variety is especially promising as a parent because it transmits large size, desirable shape, and high acidity of fruit, and hermaphroditism to many or all of its seedlings. As later crosses have come into fruiting, the earlier conclusion that the Lloyd George variety is a valuable parent for breeding new varieties for this locality have been substantiated. Additional data relative to fruit and plant characters and observations relative to inheritance and breeding behavior are presented in this paper.

PRESENTATION OF DATA

Data relative to fruit characteristics are given in Tables I to III. It is conceded that it is almost impossible to classify a large number of plants accurately on the basis of flavor of fruits or size of fruits because of seasonal and environmental variations and the variable reactions of the investigator. The data for these characteristics are believed to be sufficiently accurate, however, to serve as an indication of the comparative breeding behavior of the different varieties. These data are additional to those previously published.

TABLE I—INHERITANCE OF FRUIT SHAPE IN RED RASPBERRY CROSSES

Cross (and Reciprocal)	Round and Hemispherical		Round-conic		Conic		Oblong-conic	
	No. Plants	Per cent	No. Plants	Per cent	No. Plants	Per cent	No. Plants	Per cent
Marlboro x Lloyd George	2	1.4	53	37.3	87	61.3	—	—
King x Lloyd George....	5	3.7	61	45.2	68	50.4	1	0.7
Antwerp x Lloyd George	—	—	1	8.3	10	83.3	1	8.3
Latham x Lloyd George.	—	—	26	16.3	120	75.0	14	8.7
Cuthbert x Lloyd George	—	—	9	5.6	103	64.4	48	30.0
Latham x Cuthbert.....	5	4.9	29	28.4	65	63.7	3	2.9
King x Antwerp........	20	46.5	21	48.8	2	4.7	—	—

[1]Published as Scientific Paper No. 303, College of Agriculture and Experiment Station, State College of Washington.

Fruit shape:—Northwest canners, familiar with the characteristics of the Cuthbert variety, favor a conic or oblong-conic red raspberry. Table I indicates that the cross Cuthbert x Lloyd George gives a very high percentage of desirable fruit shapes. Latham x Lloyd George also gives a high percentage of conic-fruited hybrids. Lloyd George crossed with a conic-fruited variety, such as Cuthbert, apparently gives a higher percentage of conic-fruited hybrids than when crossed with a variety having hemispherical fruits, such as King. The data do not, however, support our former conclusion (1) based upon a smaller number of crosses, that Lloyd George represents the homozygous dominant condition for fruit shape. It does not seem possible to explain the inheritance of raspberry fruit shape on any simple factorial basis.

Fruit size:—Neither small size nor extremely large size of fruit is desirable in red raspberries for commercial purposes. Moderately large size is essential, however, to the packing of fancy grades.

TABLE II—INHERITANCE OF FRUIT SIZE IN RED RASPBERRY CROSSES

Cross (and Reciprocal)	Large		Medium		Small	
	No Plants	Per cent	No. Plants	Per cent	No. Plants	Per cent
Marlboro x Lloyd George	7	3.5	164	82.4	28	14.1
King x Lloyd George...	4	2.9	117	86.0	15	11.0
Antwerp x Lloyd George	6	50.0	6	50.0	—	—
Latham x Lloyd George	33	19.2	120	69.8	19	11.0
Cuthbert x Lloyd George	12	7.7	130	83.3	14	9.0
Cuthbert x Marlboro...	—	—	16	53.3	14	46.7
Cuthbert x Antwerp....	2	3.2	40	63.5	21	33.3
King x Antwerp.......	—	—	13	28.3	33	71.7

Data in Table II indicate that the crosses Cuthbert x Lloyd George and Latham x Lloyd George have given the highest percentages of large-fruited hybrids of the crosses reported. Several seedlings of the Latham x Lloyd George cross bear fruits that probably are too large to hold up well in commercial handling and packing. Certain crosses, such as King x Antwerp and King x Marlboro (1) contain no plants which bear fruits of suitable size for commercial purposes.

Fruit flavors:—Any attempt to evaluate fruit flavors is a difficult undertaking and this is no less true of red raspberries than of other fruits. After repeated sampling of fruits of hybrids which vary in flavor over a wide range, it is concluded that acidity and sugar content depend upon independent factors.. Tannins probably are important also in the production of red raspberry flavors. For purposes of genetic analysis these factors should be determined and classified separately. In attempting to evaluate several crosses on the basis of the number of plants bearing fruits of desirable flavor, it seems possible to use an arbitrary classification. In recording the data in Table III, those berries whose acidity was so great as to be objectionable for commercial purposes were classed as "acid" while those which were decidedly lacking in flavor were classed as "insipid." Thus the most desirable flavors are included under "sweet" and "subacid."

Subacid fruits would require the addition of sugar and might, therefore, be better adapted to processing or freezing than to fresh market purposes from the standpoint of flavor. The "sweet" class includes hybrids whose flavor is predominately sweet as well as those which are best described as a combination of sweet and subacid. The latter are the most desirable flavors for commercial purposes.

TABLE III—THE INHERITANCE OF FRUIT FLAVOR IN RED RASPBERRY CROSSES

Cross (and Reciprocal)	Insipid		Sweet		Subacid		Acid	
	No. Plants	Per cent	No. Plants	Per cent	No. Plants	Per cent	No. Plants	Per cent
Marlboro x Lloyd George	12	8.8	16	11.8	74	54.4	34	25.0
King x Lloyd George....	7	5.3	26	19.5	57	42.9	43	32.3
Antwerp x Lloyd George	—	—	—	—	5	45.5	6	54.5
Latham x Lloyd George.	7	4.5	10	6.4	53	34.0	86	55.1
Cuthbert x Lloyd George	4	2.7	45	30.2	52	34.9	48	32.2
Cuthbert x Marlboro...	5	17.2	6	20.7	12	41.4	6	20.7
Cuthbert x Antwerp....	5	8.8	14	24.6	16	28.1	22	38.6
Latham x Cuthbert.....	5	5.1	23	23.5	39	39.8	31	31.6
King x Antwerp........	4	9.8	1	2.4	10	24.4	26	63.4

It is evident from Table III that a good percentage of well-flavored hybrids occur in several crosses in which Lloyd George or Cuthbert is one of the parents. Crosses between Lloyd George and Cuthbert have produced several seedlings which approach Cuthbert in flavor of fruit and contain nearly all of the seedlings which have been selected because of desirable fruit flavor. No seedlings have been selected because of outstanding flavor of fruit from crosses involving King, Marlboro, Antwerp, and Latham excepting the crosses in which Cuthbert or Lloyd George was the other parent.

Seedling selection:—The bases for seedling selection include desirable plant type, desirable size, shape, color, and flavor of fruit and early to mid-season maturity. The number of seedlings selected from various crosses for propagation and further testing are shown in Table IV.

The data emphasize the outstanding value of the Lloyd George as a parent, especially when crossed with high quality varieties such as the Cuthbert.

The seeds which gave rise to the open-pollinated Lloyd George seedlings were obtained from the fall crop on young plants in 1929. M. B. Hardy, who collected the seeds, believed that they had resulted from self-pollination or largely so, because few if any flowers were observed on other varieties at the time that these seeds were set. The vigor of most of the open-pollinated seedlings and the outstanding fruit characteristics of many of them as contrasted with small populations of strictly inbred Lloyd George seedlings have cast much doubt upon this assumption. However, no great similarity has been noted between this population and those resulting from any Lloyd George cross. A high percentage of the plants bear very acid

TABLE IV—RASPBERRY SEEDLING SELECTIONS

Cross	Total Number Plants	Number Selected	Per cent Selected
Lloyd George open pollinated	268	22	8:2
Lloyd George x Cuthbert	136	17	12.5
Cuthbert x Lloyd George	144	12	8.3
Latham x Lloyd George	89	3	3.37
Lloyd George x Latham	141	4	2.84
Lloyd George x King	86	1	1.16
King x Lloyd George	79	1	1.27
Cuthbert x Marlboro	46	3	6.5
Marlboro x Cuthbert	210	4	1.9
Cuthbert x Latham	49	2	4.08
Latham x Cuthbert	196	1	0.51
King x Cuthbert	128	3	2.34
Antwerp x Lloyd George	18	2*	11.11
Cuthbert x Antwerp	140	1	0.71
Cuthbert x King	17	0	0
Marlboro x Lloyd George	307	0	0
All Marlboro, King, Latham and Antwerp crosses inter se	1013	0	0
Inbred populations	309	0	0
Totals	3377	76	2.25 (av.)

*Selected for earliness and large size respectively, inferior in quality.

fruits which are oblong-conic in shape and generally too soft in texture for use as commercial varieties. The best of the selections from this population is inferior in flavor of fruit to several of the Lloyd George x Cuthbert hybrids. A further study of the results of open-pollination and inbreeding of the Lloyd George variety would seem to be justified.

Observations relative to the value of different red raspberry crosses support the conclusions of Slate (2) that "populations in which a high percentage of promising seedlings appear usually contain the most promising seedlings as well. Promising crosses should, therefore, be repeated on a larger scale, since in general the percentage of crosses giving good results is low."

A few seedlings of considerable merit have been selected from the crosses Cuthbert x Marlboro, Cuthbert x King, and Latham x Lloyd George.

In many fruit breeding experiments final selections are made during the first year that the seedlings are in fruit. Our experience indicates that the best qualities of many red raspberry seedlings do not appear in the first fruiting season. In most cases, our outstanding hybrids have been selected during the second fruiting season after having been rejected as inferior during the previous season.

The Hardiness Factor

Since hardiness is one of the principal objectives in our breeding experiments, a study is being made of the factors contributing to hardiness of varieties in the climate of western Washington and the transmission of hardiness in various crosses. Results of artificial

freezing tests support the conclusion from field observations that Lloyd George, King, Marlboro, Antwerp, and Latham are much more winter-resistant than is Cuthbert in the climate of western Washington. The results of studies with hybrid seedlings indicate that most of the Lloyd George x Cuthbert hybrids and all of the hybrids of more hardy parentage are superior to Cuthbert in cold resistance.

Conclusions

Further observations based on additional crosses with Lloyd George and several other varieties of red raspberries support the former conclusion that the Lloyd George is of outstanding value for breeding new varieties for commercial purposes in the climate of western Washington.

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Breeding Strawberries for a Particular Ripening Season[1]

By J. HAROLD CLARK, *N. J. Experiment Station, New Brunswick, N. J.*

THE New Jersey Experiment Station has been breeding strawberries since 1928 with the definite object in view of producing commercial varieties which ripen very late. The reason for concentrating on varieties for this season is that the eastern markets are usually well supplied with strawberries from Delaware, Maryland and other sections up to the middle of the New Jersey season. After the New Jersey crop is harvested, however, prices usually rise because the acreage in the late producing sections is relatively small. This situation has made New Jersey growers anxious to find a good late variety to extend the picking season.

Many late varieties were tested at New Brunswick but none of them were very satisfactory for commercial production. Apparently the only way to secure a good variety, adapted to local conditions, was to originate it, and so breeding experiments were started.

Very little was known about the efficacy of our standard strawberry varieties in transmitting to their offspring a tendency to ripen at a certain season. Cummings and Jenkins (1) found that when early and late varieties were crossed, the progeny were intermediate but no information was given in their report as to the range or variation in ripening dates. It was assumed, however, that late ripening varieties when crossed would produce late ripening progeny. Most of the late ripening varieties have some serious fault and so it seemed desirable to use midseason or even early varieties for such characters as quality, firmness, productiveness, and vigor. Most of the varieties used as parents at the start were well known standard sorts but later several seedlings originated by Dr. G. M. Darrow of the U. S. Department of Agriculture were included, and more recently New Jersey selections have been used freely.

Since the date of ripening of seedlings has an important bearing on their possible economic value, it seemed worth while to present some figures on the date of ripening of the progeny of several well known varieties. Space does not permit presentation of data from all the crosses made between named varieties, and none of the crosses in which New Jersey selections were used as parents are included.

The parent varieties were grown in matted rows. Each seedling, however, was permitted to make a block of plants about 2 feet square after which runners extending beyond that limit were cut off.

With this one exception all the plants, including parent varieties and their progeny were grown under uniform conditions of culture, mulching, etc.

As shown in Table I, the date when a variety was ready for first picking was selected as the criterion of the date of ripening. The seedlings of a particular cross are considered from two standpoints—

[1]Journal Series paper of the New Jersey Agricultural Experiment Station, Department of Pomology.

TABLE I—DATE OF RIPENING (FIRST PICKING) OF CERTAIN STRAWBERRY VARIETIES COMPARED WITH DATE OF RIPENING OF THEIR PROGENY

Parent Varieties				Seedlings		
Female Parent	First Picking	Male Parent	First Picking	Number Recorded	Range of First Picking	Date 50 Per cent Ready for First Picking
1930	*June*		*June*		*June*	*June*
Aberdeen	8	Howard 17	2	124	*31–12	6
Howard 17	2	Aberdeen	8	150	1–12	7
Aberdeen	8	Lupton	9	147	4–17	11
Lupton	9	Aberdeen	8	149	5–19	11
Aberdeen	8	Wyona	13	82	4–18	13
Aberdeen	8	Gandy	12	126	7–17	12
Pearl	12	Aberdeen	8	148	7–18	13
Gandy	12	Howard 17	2	175	4–16	10
Lupton	9	Howard 17	2	54	5–11	8
Mastodon	4	Howard 17	2	54	1–12	4
1931						
Aberdeen	11	Selfed	—	20	8–18	15
Chesapeake	10	Selfed	—	9	9–21	18
Gandy	15	Selfed	—	24	16–20	19
Howard 17	2	Selfed	—	8	4–8	6
Lupton	10	Selfed	—	11	8–15	9
Pearl	18	Selfed	—	32	17–29	25
Wyona	18	Selfed	—	16	15–23	18
Aberdeen	11	Mastodon	11	38	6–15	9
Mastodon	11	Aberdeen	11	34	6–17	9
Aberdeen	11	U.S.D.A. 875	14	47	8–22	15
U.S.D.A. 875	14	Aberdeen	11	50	9–19	15
Chesapeake	10	Aberdeen	11	26	7–15	12
Chesapeake	10	Pearl	18	46	8–22	17
Gandy	15	Aberdeen	11	42	6–18	14
Gandy	15	Chesapeake	10	15	9–22	17
Gandy	15	Pearl	18	49	5–20	13
Howard 17	2	Lupton	10	27	6–15	8
Howard 17	2	Wyona	18	20	5–14	8
Lupton	10	Chesapeake	10	16	9–15	13
Lupton	10	Pearl	18	40	7–17	13
Lupton	10	Wyona	18	39	8–19	15
Pearl	18	Howard 17	2	70	6–17	9
Pearl	18	Wyona	18	70	9–22	18
Wyona	18	Pearl	18	33	9–22	17
Wyona	18	U.S.D.A. 875	14	50	9–20	17
U.S.D.A. 875	14	Pearl	18	50	12–25	19
1932						
Aberdeen	13	Mastodon	13	35	7–19	14
Mastodon	13	Aberdeen	13	39	8–18	14
Redheart	14	Mastodon	13	97	6–19	13
Parcell	20	Redheart	14	39	8–21	14
Teddy R.	15	Redheart	14	62	7–25	18
Redheart	14	Aberdeen	13	47	8–21	14
1933						
Pearl	11	Selfed	—	11	19–21	20
Fairfax	6	Selfed	—	25	5–16	12
Fairfax	6	Aberdeen	6	52	5–15	12
Pearl	11	Fairfax	6	42	5–21	15
Teddy R.	10	Pearl	11	64	12–23	16
Teddy R.	10	Fairfax	6	76	6–16	12

*May.

first, the range of ripening dates; and second, the average date when 50 per cent of the seedlings had reached the first picking stage.

There is, of course, considerable variation in the ripening date of each variety from year to year and even in the order of ripening of different varieties, and so the actual ripening date of each parent is recorded each time it is listed.

Discussion of Results

The data included in Table I indicate that reciprocal crosses, as would be expected, gave progeny ripening at approximately the same time. Early varieties when crossed with early varieties gave mostly early ripening seedlings. Late varieties crossed with early varieties gave seedlings most of which ripened in midseason. Late varieties crossed with other late varieties gave mostly late ripening seedlings.

The range of ripening dates is important, as it gives some indication as to whether extremely early or extremely late seedlings might be obtained from a given cross if sufficient numbers were raised. On the average, there was a period of about 12 days from the time the first seedling of a cross ripened until the latest ripened, although in the Teddy R. x Redheart progeny, the range was from June 7 to June 25, or 19 days. The greatest total range for any one year of all seedlings from crosses here reported was from June 5 to June 25, 1931, or a period of 21 days. This may not represent the greatest possible range since no crosses between very early varieties are recorded.

It is significant that in all but eight of the crosses listed in Table I, some seedlings ripened earlier than the early parent and others ripened later than the late parent. Five of these exceptions were Howard 17 crosses in which no seedlings ripened as early as that variety. This indicates that there are possibilities of securing desirable new varieties ripening later than the standard varieties now available. Some selections, especially from F_2 generations, which show some promise as very late varieties have already been made.

In order to throw as much light as possible on the breeding behavior of certain varieties, it seemed advisable to include records of progenies produced from selfed seed, even though the number of individuals is rather small. It will be noted, for instance, that Pearl and Wyona ripened on the same date in 1931, yet the selfed seedlings of Pearl were later on an average than the selfed seedlings of Wyona. In various crosses, Pearl seems to produce late ripening seedlings more consistently than does Wyona. Lupton selfed gives seedlings ripening in midseason and Lupton crossed with other varieties tends to produce midseason seedlings. Chesapeake, however, which ripens about with Lupton, when selfed gives late ripening seedlings and when crossed with other varieties tends to produce late ripening seedlings. There is additional information at hand but not included in Table I which indicates that some midseason sorts have a decided tendency to produce late seedlings. The ripening dates of the offspring, therefore, cannot always be determined from the season of the parents, although usually the general range may be predicted fairly well.

It is reasonable to expect that varieties used as parents in certain combinations may behave differently than the same varieties used in other combinations, in so far as transmitting a tendency towards late ripening is concerned. For instance, seedlings of Chesapeake x Pearl are much later than Chesapeake x Aberdeen, but seedlings of Gandy x Pearl are no later than seedlings of Gandy x Aberdeen. There are indications of similar response in other combinations, but the data are not extensive enough to warrant general conclusions.

These results, on the whole, conform to what we know about inheritance in other fruit plants. Nothing has been observed to indicate that the strawberry behaves differently from other plants with respect to transmission of the factors affecting date of ripening.

The varieties recorded in Table I might be grouped according to their tendency to produce early or late ripening progeny. Howard 17 and Mastodon have a tendency to produce early ripening offspring. Aberdeen, Fairfax, Lupton, and Redheart tend to produce seedlings ripening in midseason. Chesapeake, Gandy, and Parcell tend to produce late ripening seedlings. Pearl, Teddy R., U. S. D. A. 875, and Wyona tend to produce very late seedlings.

Summary

The dates of ripening of certain strawberry varieties used as parents are presented in comparison with the ripening dates of their offspring. The average date of ripening of seedlings tended to be intermediate with respect to the parents. Seedlings from the crosses listed usually showed a range of ripening dates extending well beyond the range of the two parents. The dates of ripening of selfed seedlings of a variety appeared to indicate roughly the ability of that variety, when used as one parent in a cross, to transmit early or late ripening characteristics to its offspring. Certain varieties are listed according to their tendency to produce seedlings ripening at a particular season.

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The Effect of Rainfall During the Picking Season on Size and Yield of Certain Strawberry Varieties[1]

By W. H. Childs, *West Virginia University, Morgantown, W. Va.*

IT is commonly accepted that irrigation will increase yields of strawberries when soil moisture conditions are unfavorable, and that it is generally profitable where a water supply is available and too great an initial expenditure for equipment is not required. Differences in varietal responses to applications of water, however, apparently have not often been considered. Data obtained while carrying on strawberry variety tests at the Lakin Experiment Farm in Mason County, West Virginia, indicate possibilities in experimentation along this line.

The strawberry variety planting at Lakin consisted of an area of fine sandy loam laid out systematically in blocks with Premier (Howard 17) planted every third row as a check, and each variety replicated seven times. The plants were set in the spring of 1933. Good matted rows were produced in practically all cases. Records taken during 1934 included size and yield of fruit at each picking and daily rainfall.

Precipitation during the first four months of 1934 had totaled only 7.59 inches, and this abnormal drought condition continued into June. As a result, moisture was a limiting factor in production, and the effects of rainfall were very pronounced. The effect of rainfall on size of berry and on yield for several varieties is shown on the accompanying graph and tables. Yield records are given for each picking of each variety, but records of size are shown from June 2 to 15 only, because production was too small for an accurate count at the beginning and end of the season.

Results and Discussion

Both size and yield of fruit were affected from day to day by rainfall. The first picking of Premier was made on May 25, that of Blakemore, Bellmar, Glen Mary, Culver, and Clermont on May 28, and of the rest, with the exception of Gandy, on May 31. By June 5 all varieties except Gandy had begun to drop off rapidly in size. Most of the varieties had produced their largest picking on June 2, and had dropped off considerably in yield also on June 4 and 5. On the afternoon of June 5, 0.59 inch of rain fell, and the effect was very noticeable at the next picking, June 7. The size of berries of Glen Mary, Culver, Blakemore, and Clermont immediately increased; that of berries of Aroma, Bellmar, Premier, and Gandy stayed about the same as at the previous picking; while the rate of decrease in size was lessened for the other varieties, although it was not entirely stopped. The yield also increased greatly, being the largest of the season for all but three varieties. Gandy was just beginning to ripen and was but slightly affected; Premier had been producing for 12

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TABLE I—EFFECT OF RAINFALL ON YIELD OF STRAWBERRIES

Date	Rainfall (Ins.)	Quarts per 300 Feet of Row												
		Premier	Fairfax	Dorsett	Blakemore	Bellmar	Culver	Clermont	Aberdeen	Glen Mary	Big Joe	Chesapeake	Aroma	Gandy
May 25	—	16.6	—	—	—	—	—	—	—	—	—	—	—	—
28	—	9.9	—	—	2.9	1.9	1.1	0.9	—	0.9	—	0.2	—	—
31	—	35.9	4.5	3.3	16.7	13.1	22.2	13.3	2.5	7.7	1.5	2.7	3.8	—
June 2	—	37.8	24.2	24.0	26.0	22.6	18.0	22.8	7.6	15.6	8.3	4.9	8.3	—
4	—	18.5	16.6	17.8	17.8	17.9	16.7	16.8	12.9	12.9	14.8	6.3	17.3	0.8
5	0.59	14.1	9.0	11.7	12.5	11.8	6.4	9.0	11.8	7.6	9.1	7.4	10.7	1.5
7	—	31.1	40.2	39.2	36.7	32.3	13.8	23.8	31.4	22.6	24.4	21.1	24.6	9.5
9	0.24	20.1	36.1	23.9	18.6	19.7	17.5	20.8	30.7	18.1	15.5	15.9	18.9	18.0
11	0.25	15.4	33.4	15.8	19.9	16.1	10.4	12.6	24.4	17.4	15.8	15.0	22.4	23.7
13	0.13	4.3	23.9	2.3	5.8	3.8	4.7	13.1	15.6	8.9	6.3	8.7	8.3	14.7
15	—	2.7	13.0	3.5	2.5	0.8	5.7	5.2	9.7	4.8	5.2	4.5	2.7	12.2
16	—	—	2.3	0.7	—	—	1.7	2.5	1.8	1.0	0.6	0.9	0.4	2.1
18	—	—	1.2	—	—	—	3.3	2.5	1.6	1.5	1.2	1.5	0.7	5.1
19	1.91	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	2.5	—	—	—	1.6	1.4	1.1	1.2	0.9	1.3	0.6	5.2
Total	3.12	206.4	206.9	142.2	159.4	140.0	123.1	144.7	151.1	120.2	103.6	90.4	118.7	92.8

TABLE II—EFFECT OF RAINFALL ON SIZE OF STRAWBERRIES

Date	Rainfall (Ins.)	Number per 2000 Gms												
		Premier	Fairfax	Dorsett	Blakemore	Bellmar	Culver	Clermont	Aberdeen	Glen Mary	Big Joe	Chesapeake	Aroma	Gandy
June 2......	—	343	167	247	378	298	333	301	280	304	263	207	197	—
4......	—	476	230	337	560	422	415	365	329	470	422	279	266	—
5......	0.59	569	273	361	666	547	545	460	383	812	439	325	310	310
7......	—	564	304	424	591	550	455	416	473	550	524	348	314	295
9......	0.24	788	445	561	883	788	594	444	539	609	632	370	390	346
11......	0.25	914	548	746	1126	1097	524	661	605	634	810	339	523	464
13......	0.13	850	653	829	1253	1114	667	735	699	637	827	595	685	557
15......	—	900	1240	949	1511	1739	548	583	1044	488	1191	701	1013	763

days, so the green berries were becoming a little scarce, and the yield did not quite reach that of June 2; Culver reached its peak at the second picking and was not stimulated enough to yield an equal or greater quantity.

After the June 7 picking, most of the varieties decreased in size at about the same rate as before the rain, but its effects seemed to be prolonged somewhat with Glen Mary, Chesapeake, and Clermont. A 0.24-inch rainfall on June 9 had no noticeable effect on some varieties, and little on others, but Chesapeake and Culver increased in size. When another 0.25 inch fell on June 11, the effects were more noticeable. Premier increased slightly in size; Bellmar, Glen Mary, and Big Joe stayed the same size as at the previous picking; and Blakemore, Fairfax, Aroma, Dorsett, Clermont, Gandy, and Aberdeen decreased less rapidly.

The light rain (0.13 inch) on June 13 had no measurable effect excepting on Glen Mary, Culver, and Clermont, which increased in size. The heavy rain on June 19 came too late to be of any value. Though yields probably were prevented from dropping more rapidly by the rainfall on June 9 and 11, they were not increased over the previous pickings.

From the data obtained during this single season, it seems probable that some varieties of strawberries give a greater response to irrigation than others. The data for 1934 was incidental to a general variety experiment, and such possible causes as difference in root systems and number of plants to the square foot were not studied. It is intended to continue this test at least another season and see if results are similar, and what factors appear to be responsible for the differences between varieties.

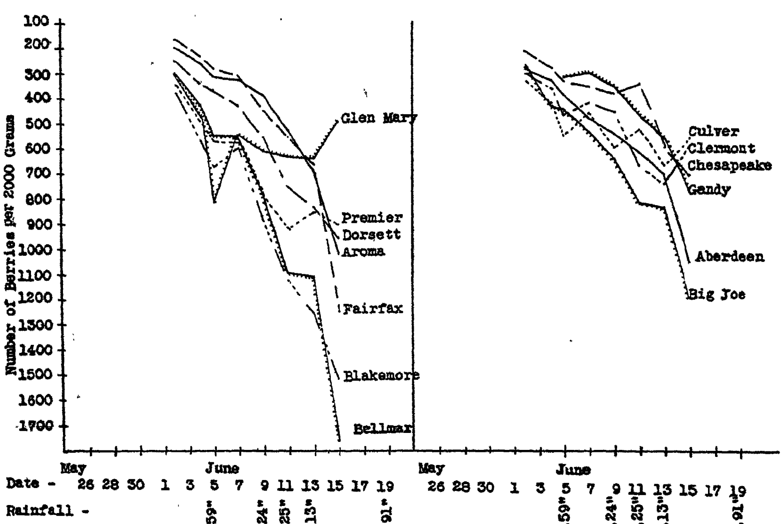

FIG. 1. Effect of rainfall on size of strawberries.

Strawberry Runner Plant Production in Southwest Texas

By E. Mortensen, *Texas Experiment Station, Winter Haven, Tex.*

SOUTHWEST Texas climate is favorable to the production of strawberries for early spring marketing but the summers are unfavorable for the formation of runner plants. The strawberry growers of southwest Texas follow a system of production similar to that of Hammond, Louisiana, (5) and Florida (2) in which the plants are set in the fall for a fruit crop the following spring. Experiments have shown that best crops are obtained with close spacing using about 30,000 to 40,000 plants per acre. Thus it is readily seen that one of the chief requisites to successful production of strawberries in southwest Texas is the efficient production of runner plants during the summer months.

Temperatures rise about May 1 to daily means above the optimum of 73 degrees F as indicated for best plant development by Darrow (3). Shallow rooted crops like strawberries would suffer severely in such temperatures unless means were taken to keep the soil cool. Some possibilities along this line are shading, mulch, and frequent irrigations. Heat resistant varieties would also be important as well as varieties that would produce runners freely under high temperatures.

Previous work at Beeville, Texas, in saving the plants through the summer showed that a high percentage can be saved through applying cottonseed hulls as a mulch following the picking season and removing it in October (1). This, however, was for plants grown in the matted row and did not have the object of plant production. Various crops for shade have been tried by growers such as popcorn, castor beans, okra, sesbania, cowpeas, and field corn.

Treatments tried in 1931 following the picking season in a field of Missionary strawberries included (a) corn for shade, (b) weeds allowed to grow for shade, (c) clean cultivation, (d) straw mulch. Plats were 109 feet long and consisted of two rows 24 inches apart with plants 18 inches apart in the row. They were irrigated every 10 to 14 days when not raining. The period from May 15 to August 15 had unusually heavy rainfall. A good test of the treatments did not occur until after August 15. The straw mulch gave the best survival of mother plants (Table I). The weed plats were obviously failures. The clean treatment, corn for shade, and straw mulch were practically equal in the yield of "select" plants on October 15, although the greatest yield of total runner plants was from the straw mulch treatment. The straw mulch interfered with irrigation and did not permit the rooting of runner plants until the straw had somewhat decayed.

Heat and drought checked plant formation considerably in September but later tests indicate that this might have been overcome by more frequent irrigations. Considering all features the clean cultivation seemed the most efficient.

TABLE I—COMPARISON OF TREATMENTS IN RUNNER PLANT PRODUCTION, 1931

Treatment	Per cent of Total Surviving Runner Plants Rooted by Periods					Runner Plants per Original Parent	Per cent Select Plants	Mortality Parent Plants (Per cent)
	6/15	7/15	8/15	9/15	10/15			
Clean	8	33	28	8	23	11.5	25	28.5
Weeds	38	80	35	-37*	-16*	2.1	18	52.0
Corn	10	32	18	9	31	9.1	36	24.0
Straw mulch	2	17	43	6	32	13.7	22	21.5
Rainfall (Ins.)	4.24	3.03	5.86	0.60	0.00	—	—	—
Temperature (Degrees F)	78.3	83.5	83.0	82.6	83.0	—	—	—

*Due to death of runner plants.

The following year Carolina (Missionary) plants were set on March 23, keeping the flower clusters picked off in the spring. Only two treatments were used, namely, (a) clean cultivation and (b) corn for shade. Plants were set 3 by 3 feet and counts were made on single rows 50 feet long with three plats of each treatment. The results show very little difference in the treatments (Table II). However, it is apparent that high temperatures affect the runner plant production. A high mortality of parent plants was obtained, most of which occurred in the period ending August 22 with an average daily mean temperature of 88.5 degrees F. In the following period ending September 13 only a small mortality occurred with an average daily mean of 80.6 degrees.

TABLE II—COMPARISON OF TREATMENTS IN RUNNER PLANT PRODUCTION, 1932

Treatment	Per cent of Total Rooted by Periods			Runner Plants per Original Parent	Mortality (Per cent) O P
	July 20	Aug. 22	Sept. 13		
Corn	92	-7	15	11.6	45
Clean	97	-16	19	10.1	43
Rainfall (Ins.)	4.80	2.74	5.72	—	—
Temperature (Degrees F)	85.8	88.5	80.6	—	—

A comparison in 1931 of irrigations weekly and at two week intervals when not raining was not very conclusive because of the heavy rainfall. However, the weekly irrigation gave the most plants at the end of the season with the greatest difference in the period ending September 15 when the highest temperatures and low rainfall prevailed. Plats irrigated weekly averaged 16.2 runner plants per original parent while irrigations at two-week intervals gave 10.7 runner plants per original parent plant.

In 1933 an irrigation experiment using evaporation records as an index (4) was continued throughout the summer (May 1 to Nov. 1). Plats were 109 feet long with rows 18 inches apart and plants 12

inches in the row. This is rather close for the production of good plants. The results were:—48 irrigations (0.75-inch accumulated evaporation), 26.9 runner plants per original parent plant; 32 irrigations (1.25-inch interval), 25.0; 20 irrigations (1.75-inch interval) 20.4. Indications in this experiment are that frequent irrigations are needed in the summer months.

A study of runner plant formation in different varieties was made in 1932, 1933, and 1934. In 1932, 50 plants of each variety had been set in the fall of 1931 and were allowed to bear fruit in the spring. Records were kept at approximately monthly intervals. Although much significance can not be attached to such few numbers, indications of comparative heat resistance are shown by Aroma, Carolina (Missionary), New Oregon, Dunlap, Blakemore, Redheart, and Klondike. Klondike lost some plants in the latter part of the season which may have been caused by the heat.

In 1933, a more extensive test was made of runner plant formation by varieties. Two plats of each variety, consisting of single rows spaced 18 inches apart and 100 feet long with parent plants 12 inches in the row were used in obtaining the records. There were two guard rows of the same variety on either side of each plat. These had borne a crop of fruit in the spring and were set in the fall of 1932. It was intended to take monthly counts of the runner plants but by July 16 this became impossible because of the dense set of plants. The final counts were of total plants dug from the plats about December 1. Since the worst heat of the summer usually comes in July and August, it is important that varieties form their plants in June and early July in order to avoid this adverse period. From this standpoint Klondike, Missionary, Excelsior, and Thompson show up well (Table III). However it is possible when a variety is resistant to high temperatures that it can form sufficient plants to make up for the lack in the early season. Examples of this are Aroma, Banner, and Blakemore.

TABLE III—RUNNER PLANT FORMATION BY VARIETIES—1933
(Total of Two Plats)

Variety	Parent Plants		Runner Plants Rooted by Periods (Per cent)			Ratio per Original Plant—Dec. 1	
	Original No. May 16	Mortality Dec. 1 (Per cent)	May 16	June 16	July 16	Total RP	Select
Aroma	188	30.9	0	3	11	28.4	18.0
Banner	194	29.4	2	12	8	18.4	12.4
Blakemore	202	33.2	0	1	9	20.3	12.4
Champion Klondike	186	37.1	2	19	23	6.9	4.3
Dunlap	169	47.3	0	5	22	14.2	5.0
Excelsior	184	37.5	1	18	21	12.6	5.2
Klondike (Ark.)	177	36.7	7	44*	—	22.3	13.8
Klondike (Okla.)	204	14.2	14	85*	—	13.3	6.7
Missionary (Md.)	171	17.0	2	28	31	5.5	4.2
Missionary (Ark.)	190	5.8	4	29	—	22.6	13.0
Carolina (Missionary)	193	9.8	3	27	—	19.2	12.0
Thompson	200	20.5	1	19	—	17.5	11.0

*Leaf scorch killed many plants later in the season.

Nine other varieties were grown in the same test in 1933 but in rows 3 feet apart and plants 12 inches in the row. Single plats consisting of rows about 100 feet long were used with all varieties except Early Bird which had two plats. It was possible to make counts to August 16 in these plats because they had more room. Most of these formed their plants late in the season (see Table IV). Washington, Texas, and Early Bird set their plants early and the later counts showed that they were more affected by high temperatures than any of the others. Considerable heat resistance was shown by Bellmar, Evening Star, Gibson, and Redheart. In final results Early Bird and Texas gave the most runner plants.

TABLE IV—RUNNER PLANT FORMATION BY VARIETIES, 1933

Variety	Parent Plants		Runner Plants Rooted by Periods (Per cent)				Ratio per Original Parent—Dec. 1	
	Original No. May 16	Mortality Dec. 1 (Per cent)	May 16	June 16	July 16	Aug. 16	Total RP	Select
Aberdeen	97	79.4	0	0	2	23	1.2	1.2
Bellmar	105	18.1	0	0	4	13	3.5	3.3
Big Joe	97	53.6	0	0	5	17	2.5	2.4
Early Bird—2	171	43.3	0	9	20	–5	15.4	11.3
Evening Star	82	33.2	0	2	11	15	9.8	6.0
Fruitland	101	40.0	0	3	26	22	3.6	2.4
Gibson	99	30.0	0	1	10	25	4.4	3.7
New Oregon	92	69.6	0	2	14	19	5.5	4.7
Redheart	109	31.2	0	0	1	7	1.6	0.8
St. Louis	97	35.1	0	0	14	33	3.6	3.2
Texas	101	14.0	1	12	27	1	11.0	8.0
Washington	104	26.9	8	73	53*	0	6.4	4.7

*Lost some plants later in the season.

In 1934 seven varieties were compared in rows 3 feet apart, 50 feet long, and plants 12 inches in the row. Single plats only were used. No counts were made during the summer because of illness. Plants were set March 20 and runner plants dug on September 29. Due to unusually high temperatures and low rainfall, runner plant formation was delayed until late. As shown in Table V fewer runner plants

TABLE V—RUNNER PLANT FORMATION BY VARIETIES, 1934

Variety	(50 Plants Each) Select RP per Original Parent, September 29	Mortality Parent Plants September 29 (Per cent)
Aroma	5.0	22
Banner	3.7	12
Blakemore*	3.4	24
Carolina (Missionary)	9.2	16
Excelsior	6.9	12
Klondike	5.0	46
Thompson	5.4	12

*Suffered from Yellows.

were obtained than in 1933. Carolina (Missionary) gave best results with Excelsior second. Lowest mortality of parent plants occurred with Banner, Excelsior, and Thompson. Klondike had a high mortality.

Considering all 3 years' results, the best varieties for runner production of those tried were Missionary, Klondike, Aroma, Thompson, and Blakemore. Of the treatments, clean cultivation with frequent irrigation (1.00 to 1.25 inches accumulated evaporation or about every 3 to 5 days when not raining) seemed the most practical. Shade crops are of doubtful value since they rob the plants of both food and moisture. Mulching would be valuable in carrying through the plants already formed but interferes with rooting of new plants.

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Relation of Temperature of Fruit to Firmness in Strawberries

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A STUDY of the influence of certain factors on the firmness of strawberries has been made and the relation of dry weight to firmness has been reported (1) previously. The effect of temperature is considered in this paper.

Using a needle type puncture tester Hawkins and Sando (2) found that the resistance of the epidermis of strawberries to puncturing increased with decreased temperature. From this they considered that the fruit would be less susceptible to mechanical injury and to penetration by decay organisms at low temperatures than at high temperatures.

Material and Methods

The strawberries for these investigations were obtained from the experimental plots at Glenn Dale, Maryland. After picking they were taken to the Cold Storage Laboratory at Arlington, Virginia, where they were sorted for uniform size and maturity and placed at the desired temperatures. The firmness of the berries was usually determined on the following day when they had reached the storage temperature. In the first experiments a pressure tester with a plunger ¼ inch in diameter that penetrated the fruit to a distance of ¼ inch, was used. In the later experiments a squeeze tester (1), that measures the resistance of the berries to pressure between two flat disks, was used.

Results with Plunger Type Pressure Tester

In the first experiment (1928) an unnamed seedling was used. The berries were divided into two lots, one of which was placed at 70 degrees F and the other at 36 degrees. At the time of storage the temperature of the berries was 72 degrees and the average pressure test was 215 grams. After only four hours at 36 degrees the berries had reached a temperature of 38 degrees and the average pressure test had increased to 244 grams while the pressure test of the berries held at 70 degrees had decreased to 196 grams. After 22 hours the pressure test at 70 degrees was still 196 grams but at 36 degrees it had increased to 261 grams.

Two varieties in 1928 and three in 1931 were held at various temperatures from 32 to 70 degrees and the firmness of the fruit was determined after about 15 hours at these temperatures, using 50 berries for each test. In all cases there was a consistent increase in firmness with a decrease in temperature. The average of all five lots are presented in Fig. 1, and show an increase in pressure test of 39 per cent from 70 to 32 degrees.

Results with Squeeze Tester

Similar experiments were conducted in 1933 and 1934 using a squeeze tester. Five varieties with 50 berries for each test were used

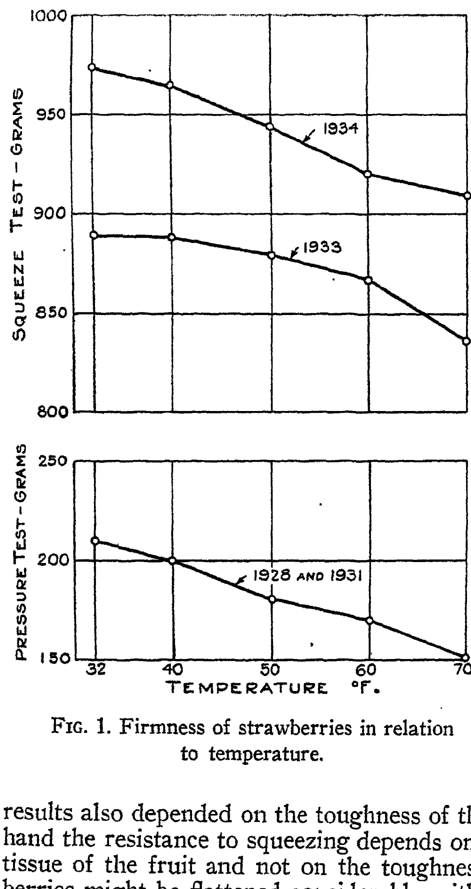

FIG. 1. Firmness of strawberries in relation to temperature.

in 1933 and four varieties with 75 to 200 berries for each test in 1934 and the average results for each year are presented in Fig. 1. The results show a slight though significant increase in firmness with a decrease in temperature. The average increase in firmness from 70 to 32 degrees was only 6.3 per cent in 1933 and 7.3 per cent in 1934.

DISCUSSION

The resistance of strawberries to penetration by a plunger ¼ inch in diameter seemed to depend more upon the toughness of the epidermis than upon the firmness of underlying tissue. The results with the ¼-inch plunger are similar to those obtained by Hawkins and Sando (2) with a needle plunger 1/40 inch in diameter with which the results also depended on the toughness of the epidermis. On the other hand the resistance to squeezing depends on the firmness of the entire tissue of the fruit and not on the toughness of the epidermis as the berries might be flattened considerably without rupturing the epidermis. As measured by the squeeze tester temperature had only a slight effect on the firmness of the berries. These results indicate that cooling of strawberries would increase their resistance to skin breaks but would have little influence on the crushing of berries.

In using a pressure tester on strawberries as a laboratory instrument to compare the firmness of different varieties or to compare the firmness of berries grown under different cultural conditions these results indicate that the temperature of the fruit might influence the reading considerably if a plunger type pressure tester is used but only to a slight extent if a squeeze type tester is used.

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The Germination of Strawberry Seeds and the Technic of Handling the Seedlings

By E. M. HENRY, *Tennessee Experiment Station, Knoxville, Tenn.*

IN connection with a strawberry breeding project, careful attention has been given during the past 3 years to some of the factors influencing seed germination and to the technic of handling the seedlings. Through such an investigation it was hoped that new scientific facts could be brought out, and that an efficient method of handling the seedlings could be perfected. Being able to depend upon a given number of seeds to produce a maximum number of seedlings, one can devote more care to the pollinating technic in producing hybrids of a known parentage.

SEED GERMINATION

The study on seed germination was conducted with some of our commercial varieties, and may not be applicable to all Fragaria species.

The seeds were taken from fresh berries with forceps and placed between two layers of moist blotter paper in petri dishes. These were held at 25 degrees C in an electric oven except as otherwise stated. Notes were taken at regular intervals on the percentage of germination, and water was added when needed.

Results indicated that the seeds of Fragaria reach a sufficient stage of maturity to germinate prior to the maturity of the berry, and that the after-ripening period is very short. Some seeds germinated that were removed from the berry when it was still a greenish-white color, 10 days before it matured. Seeds of some varieties began germinating within 4 days after they were removed from the fresh berry, while those of other varieties started much more slowly. Darrow (1) finds that the seeds of *Fragaria virginiana* germinate readily, while seeds of certain forms of *F. chiloensis* and some garden varieties may not germinate for 2 or 3 weeks. The seeds of the Blakemore and Aroma varieties germinated over a period of weeks, whereas those of the Missionary variety germinated mostly within a few days. Some varieties also gave a much higher percentage of germination, as shown in Table I.

No attempt was made to hasten the germination of the more slowly responding varieties; nor to determine whether the poor germination

TABLE I—SEED GERMINATION OF DIFFERENT STRAWBERRY VARIETIES*

Variety	No. of Seeds Used	Percentage of Germination				
		1st to 10th Day	11th to 20th Day	21st to 30th Day	31st to 40th Day	Total
Blakemore	100	7.00	20.00	12.00	7.00	46.00
Aroma	100	29.00	11.00	6.00	7.00	53.00
Dorsett	180	2.78	22.22	22.22	33.89	81.11
Premier	100	11.00	55.00	17.00	6.00	89.00
Missionary	100	55.00	34.00	4.00	1.00	94.00

*Blakemore was the paternal parent of the seeds used in this test.

of some varieties could be due to a large percentage of non-viable seeds.

The investigation indicated that the paternal parent may influence the percentage of germination, and that seeds pollinated by certain varieties may give a higher percentage of germination than those pollinated by other varieties. It appears from Table II that Blakemore and Aroma, when used as paternal parents, give a high percentage of germination, whereas Fairfax gives a comparatively low percentage.

TABLE II—EFFECT OF PATERNAL PARENT UPON THE GERMINATION OF STRAWBERRY SEEDS

Cross	No. of Seeds Used	Percentage of Germination
Missionary*xBlakemore	100	94.00
Missionary x Fairfax	295	64.75
Dorsett x Blakemore	180	81.11
Dorsett x Aroma	155	75.48
Dorsett x Fairfax	333	58.56
Blakemore x Aroma	100	69.00
Blakemore x Fairfax	230	21.74

*Female parent placed first.

Results of tests on germinating seeds of the Missionary variety under various temperatures indicate that the highest possible percentage of germination is secured at approximately 25 degrees C. A minimum temperature of approximately 15 degrees and a maximum temperature of somewhere between 35 and 40 degrees are the extremes at which germination ceases.

TABLE III—GERMINATION OF STRAWBERRY SEEDS UNDER VARIOUS TEMPERATURES*

Temperature (Degrees C)	Percentage of Germination					
	1st to 15th Day	16th to 30th Day	31st to 45th Day	46th to 60th Day	61st to 75th Day	Total
6	0	0	0	0	0	0
15	0	0	.665	.665	0	1.33
20	6.00	25.33	18.67	9.67	8.00	67.67
25	64.67	20.67	5.33	1.33	0	92.00
30	67.33	11.33	2.00	0	2.00	82.66
35	12.67	26.67	13.33	10.67	0	63.34
40	0	0	0	0	0	0

*This test consisted of three lots of 50 seeds each under each of the various temperatures.

A preliminary storage test indicated that seeds stored in clean, damp sand at 7 degrees C will germinate at the end of 18 months similarly to fresh seeds. Seeds stored dry under both cool and warm temperatures gave a very poor percentage of germination at the end of six months.

HANDLING THE SEEDLINGS

Some seeds of the Missionary variety were sown in flats containing a mixture of equal volumes of sterilized sand, loam, and peat, and kept in a greenhouse, where the temperature fluctuated between 15

and 30 degrees C, depending upon the outdoor conditions. The seeds were covered with 1/8 inch of fine sand, and the flats were partly covered with plate glass to maintain sufficient moisture at all times. Seeds planted under such conditions gave a 48 per cent germination, compared with a germination of 97 per cent for seeds handled in an oven, as previously described. It was found by planting the seeds in flats, 1½ inches apart, immediately after germinating in an oven that an 80 per cent stand of plants was secured. In addition to giving the maximum number of seedlings from a given number of seeds, the plants thus handled require a minimum of greenhouse space and grow off more uniformly than those obtained when berries are crushed and the pulp mixed with sand and sown, as is often practiced (2).

When the seedlings are to be set in the field during the fall, the seeds are germinated immediately after the berries ripen in the greenhouse, which is usually from early February through April. The seedlings are kept in flats in the greenhouse until early summer, at which time they are transplanted into 4-inch veneer dirt bands. The seedlings are allowed to grow in the dirt bands until October or November, when they are transplanted to the field. All runners are kept cut off during the summer. Seedlings thus handled are well developed, having a crown diameter averaging .97 cm by November. The use of dirt bands makes it possible to transfer the seedlings to the field successfully under conditions which would often prove fatal without such precautions. To produce seedlings for spring setting in the field, the seeds are removed from the fresh berry and stored in damp sand or between damp blotter paper at 7 degrees C until November, when they are germinated, then planted in flats in the greenhouse. They are permitted to grow to transplanting size and are then transferred into dirt bands in a sash-covered coldframe. There they are retained until set in the field, during March or April.

Each seedling is given a spacing of 4 x 4 feet in the field, where it is permitted to make a clon of runner plants approximately 2½ feet square. Late runners are kept removed to prevent any possibility of mixing among various seedlings. This method simplifies the task of securing a complete set of vegetative notes during the first summer and fall, followed by complete fruit notes the second spring. In this way all the important characters which constitute a worthy variety are considered in the elimination procedure.

It is believed that these precautions in handling the seeds and seedlings are justifiable since such factors as poor germination, variable growth, plant mortality, and requirements for greenhouse and coldframe accomodations are greatly reduced.

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Conditions Affecting Cold Resistance in Strawberries

By T. A. Steele, *Oregon State Agricultural College,* G. F. Waldo, *U. S. Department of Agriculture,* and W. S. Brown, *Oregon State Agricultural College, Corvallis, Ore.*

IN December 1932, a severe freeze caused more losses from winter injury to strawberries in Oregon than had ever been known in the history of the state. The weather prior to the freeze had been relatively warm and the rainfall heavy, causing much new growth which may have made the plants more liable to freezing injury. In order to better understand the effect of these climatic conditions, this study was undertaken to determine what factors affect hardiness in strawberry plants.

Procedure

Plants for the first tests were taken from irrigated plantings in the latter part of August 1933 and those for further tests were taken late in September. All were first and second plants of runner series and were potted in 6-inch pots, using good greenhouse soil, and placed either in cold frames or in the greenhouse. Those placed in the greenhouse received the optimum amount of water and were exposed to temperatures ranging from 65 to 85 degrees F. Those in the cold frames were exposed to natural climatic conditions, with mean temperatures ranging from 58.6 degrees F in September to 46.8 degrees F in December. Wilting percentages of the soil were found by growing sunflower plants in the soil and determining the moisture content at the wilting point of the plants.

In the first series of tests, plants of seven different varieties were used, namely, Blakemore, Corvallis, Ettersburg 121, Marshall, Narcissa, Redheart, and Wickson. In the five later series of tests Corvallis and Narcissa only were used.

All plants except the checks were exposed to low temperatures in cold storage rooms. Thermograph records showed that fluctuations in the cold storage rooms were usually not over 4 degrees. All plants of any given treatment were divided into two lots following freezing. One lot was examined soon after thawing by sectioning the crown to determine immediate injury. The other lot was placed in cold frames under natural climatic conditions until May 1, 1934, when a final examination was made. Outdoor temperatures were above normal during the winter and no freezing weather occurred.

Results

Comparison of hardiness in different varieties:—Plants of the seven varieties were taken from the field late in August and held in cold frames except while exposed to low temperature treatments. Exposures to temperatures of approximately 0, 10, 18, and 27 degrees F for 24 hours were made on three different dates, namely, October 10, November 1, and December 5. All plants of all varieties were killed at 0 degree on all dates, and also at 10 degrees on October 10 and November 1. Exposure on December 5, however, resulted in a range

of injury from all dead in the Wickson variety to all alive in the Redheart and Narcissa varieties.

Examination of plants exposed to 0 degree F for 24 hours on the three different dates showed that nearly all portions of the plants were killed. Plants were also all killed at 10 degrees on October 10, and none survived of those exposed on November 1, although there were some that showed no injury to the pith. The leaves of plants exposed to 10 degrees on December 5 were generally killed, but in Redheart and Narcissa the younger small leaves were not killed and many crowns showed no injury. The vascular tissue of many of the roots was normal. Evidence of injury could still be found in the plants remaining alive on May 1 and very little recovery took place except in the Redheart and Narcissa varieties, which developed nearly normal plants but few blossoms.

Injury noted in plants exposed to 18 degrees F on October 10 was chiefly a killing of the growing points of the crown, and the production of brown areas in the pith and cortex of the large roots. The leaves generally remained green and the fine roots white. Marshall, Ettersburg 121, and Corvallis showed little recovery. Wickson, which was seriously injured, developed many new roots and crowns. Very little injury occurred on November 1 and December 5 at 18 degrees to plants of any variety and practically none at any date in plants exposed to 27 degrees.

The number of blossoms was taken as indicative of the vigor of the plants the following spring and is given in Table I. In general, for the seven varieties the amount of bloom was not materially affected by exposure to 27 degrees F on any date, nor was it seriously affected by exposure to 18 degrees on October 10. There was evidence that Blakemore, Narcissa, Redheart,. and Wickson were stimulated to greater production of blossoms by temperatures of 18 degrees and 27 degrees.

TABLE I—NUMBER OF BLOSSOMS PRODUCED BY PLANTS EXPOSED TO 10, 18, AND 27 DEGREES F FOR 24 HOURS ON OCTOBER 10, NOVEMBER 1, AND DECEMBER 5. AVERAGE OF SIX PLANTS, EXCEPT CHECK, WHICH IS AVERAGE OF 10 PLANTS

Date of Exposure	Temperature (Degrees F)	Marshall	Corvallis	Ettersburg 121	Wickson	Blakemore	Redheart	Narcissa
Checks— no freezing	—	17.2	31.7	33.8	12.3	7.7	15.8	8.2
October 10	27	19.7	37.8	21.8	9.5	9.0	14.0	7.2
October 10	18	5.8	5.0	3.7	6.3	8.8	3.7	6.3
November 1	27	17.1	24.2	25.0	14.2	10.3	16.0	12.0
November 1	18	12.7	24.7	23.3	13.7	9.5	17.2	8.8
December 5	27	11.0	24.5	29.2	9.8	11.0	15.2	13.2
December 5	18	11.0	27.0	21.7	15.0	6.3	19.0	13.5
December 5	10	0	2.0	0	0	1.3	7.5	3.7

Cold frame and greenhouse plants compared:—Plants of Corvallis and Narcissa taken from the field late in September were exposed to freezing temperatures during the last week of December, 1933. Thirty

TABLE II—RELATION OF SOIL MOISTURE TO WEIGHT OF FRUIT AND PLANT OF HARDENED (COLD FRAME) AND NON-HARDENED (GREENHOUSE) PLANTS EXPOSED TO 6 DEGREES, 18 DEGREES, AND 22 DEGREES F FOR 24 HOURS
(Average of Five Plants; Soil Wilting Point 12.6 Per cent Moisture)

Temperature (Degrees F)	Soil Moisture	Cold Frame				Greenhouse			
		Corvallis		Narcissa		Corvallis		Narcissa	
		Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)	Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)	Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)	Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)
22	Saturated	23.4	113.2	30.9	113.5	28.1	145.5	22.0	97.1
22	Med. dry	60.8	212.5	57.2	167.0	53.8	213.4	54.1	151.9
22	Dry	69.4	233.2	60.1	174.4	75.5	243.2	51.3	155.6
18	Saturated	4.3	68.2	9.9	78.1	0	37.7	0	29.9
18	Med. dry	23.1	170.5	34.6	129.4	2.2	56.1	0	42.6
18	Dry	38.2	194.1	43.9	151.5	1.9	49.7	0	77.4
6	Saturated	0	0	0	0	0	0	0	0
6	Med. dry	0	0	0	0	0	0	0	0
6	Dry	0	0	0	0	0	0	0	0

plants from the greenhouse and 30 from the cold frame of each variety were exposed to temperatures of 18 degrees and 9 degrees F, 15 of each variety for 13 hours and 15 for 24 hours. Following exposure all plants were grown in cold frames for 4 months after which all were taken into the greenhouse for a month to hasten ripening of the fruit. The immediate, and also the final examinations of the plants 5 months later, revealed no injury to either greenhouse or cold frame plants exposed to 18 degrees, for 13 hours. However, greenhouse plants exposed to 18 degrees for 24 hours were severely injured and the yield of fruit was reduced 71 per cent for Corvallis and 95 per cent for Narcissa. In contrast the yield of fruit for cold frame plants of Corvallis and Narcissa was reduced 35 and 44 per cent, respectively, when exposed to the same treatment. All greenhouse plants were killed by exposure to 9 degrees for both 13 and 24 hours. Cold frame plants exposed to 9 degrees for 13 hours were severely injured but survived and produced a little fruit. All plants of both varieties were killed by exposure to 9 degrees for 24 hours.

Effect of soil moisture:—In a third test, 360 potted plants from both greenhouse and cold frames were divided into three sets 2 weeks prior to freezing. One set was kept saturated with water, another was given a normal amount, and the third received no water. All were exposed to freezing temperatures of 22, 18, and 6 degrees F for 24 hours. One-half (5 plants) of each set were examined 2 days after

TABLE III—EFFECT OF GRADUAL CHANGE IN TEMPERATURE UPON PLANTS GROWING IN RELATIVELY DRY SOIL (RANGING FROM 18.6 TO 24.6 PER CENT MOISTURE) BOTH IN COLD FRAME AND GREENHOUSE. SOIL WILTING POINT 12.5 PER CENT MOISTURE). AVERAGE OF FIVE PLANTS

Treatment (Hours and Degrees F)	Cold Frame				Greenhouse			
	Corvallis		Narcissa		Corvallis		Narcissa	
	Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)	Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)	Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)	Weight of Fruit (Gms)	Total Weight of Fruit and Plant (Gms)
Check....	51.2	195.4	51.0	165.0	53.2	222.3	74.0	179.0
No. 1—68 hours at 32......	46.0	243.3	85.6	200.6	46.3	218.3	149.5	306.4
No. 2—No. 1 plus 48 hours at 23.......	40.7	234.7	80.7	183.0	35.7	157.9	95.9	235.0
No. 3—No. 2 plus 24 hours at 45, plus 24 hours at 19.....	35.4	212.0	59.0	140.5	19.1	122.5	53.7	142.9
No. 4—No. 3 plus 24 hours at 6	5.1	54.2	1.2	21.2	0	0	1.2	21.2

freezing, the other set 5 months later. The results of the final examination after 5 months, given in Table II, confirms the results recorded 2 days after freezing, that plants grown in soil with high moisture content were injured more at each temperature than similar plants grown in a dryer soil. After thawing out, crowns of plants grown in a saturated soil were soft, and water exuded when they were cut. Crowns of plants grown in soil of normal moisture or in dry soil were firm with no exudation from the cut surface.

Effect of gradual change in temperature:—Plants of Narcissa and Corvallis were grown in soils that had been gradually receiving less than the optimum water supply for 2 weeks prior to exposure. They were then exposed to progressively lower temperatures. The treatments and results are given in Table III. Where thus conditioned, the plants withstood temperatures down to 19 degrees F without serious injury. Yield in the Narcissa variety seemed to have been increased by exposure to 23 degrees for both cold frame and greenhouse plants. The greenhouse plants of the Narcissa were stimulated more than were the cold frame plants by temperatures above 19 degrees, but no difference was evident in the response of the two lots at 19 degrees and 6 degrees. Cold frame plants of Corvallis withstood lower temperatures better than the greenhouse plants.

Length of exposure:—In a fifth test an attempt was made to determine whether length of exposure to low temperatures affected the amount of injury. Plants were placed in cold storage (18 degrees F) for various periods up to 60 hours. Examination of plants following freezing showed little injury after 6 and 10 hours' exposure in either greenhouse or cold frame plants. However, after 18 hours roots and foliage of greenhouse plants were injured, though not severe enough to prevent development of new roots and leaves. In the cold frame plants injury was not severe until after an exposure of 35 hours. The degree of recovery is indicated in Fig. 1, which shows graphs of the total weight of fruit and plant for the different lengths of exposure. The cold frame plants withstood the low temperature better than did the greenhouse plants.

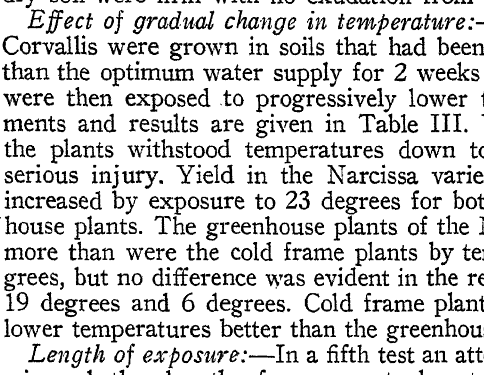

FIG. 1. Effect of length of exposure at 18 degrees F on total weight of fruit and plant of Corvallis and Narcissa strawberries 5 months later.

Age of plant in relation to resistance to injury:—Plants of the Corvallis variety of three different ages were taken from the field on October 3, potted and placed in cold frames until January 3. Mother

plants which had produced one crop of fruit the previous spring were the oldest plants used. Others were the oldest (first) runner plants which had taken root early in the summer and were large, vigorous and well rooted and the youngest (last) plants of a runner series which were small and not well rooted at the time of potting. All were exposed to 18 degrees F for 24 hours.

Final examination showed considerable injury in all plants but the oldest daughter plants were able to recover most rapidly. All showed much injury to roots and crowns and only a few blossoms appeared the following spring. Mother and oldest daughter plants formed an entirely new root system, while only small fibrous roots formed from the injured roots of the youngest plants.

Conclusions

It was quite evident that more injury to roots occurred to plants frozen in pots than would have taken place in plants grown in the field. However, root injury was not considered to be as important as injury to the upper portions of the plant. Normal crowns of strawberry plants deprived of all roots have been known to make new roots rapidly under favorable conditions. Field observations in Oregon indicate that conditions of the crown and leaves prior to freezing temperatures largely determine the resulting injury. The evidence presented here is in general agreement with field observations following the freeze of December, 1932.

The data obtained indicate that between different varieties there is a difference in the amount of injury and degree of recovery. Corvallis, Blakemore, Redheart, and Narcissa were hardier than Marshall, Ettersburg 121, and Wickson. Strawberry plants seem to endure low winter temperatures better when they have been grown in a soil that is medium dry than when grown in a well moistened or wet soil. Plants hardened by cool temperatures are less damaged by freezing than plants growing in a warm greenhouse. Sudden dropping of temperature is more injurious than gradual decline. Vigorous, well rooted plants which have not borne fruit are injured less by freezing temperatures than plants which have borne fruit, or young runner plants not well rooted.

Studies on the Stomata of Strawberry Varieties and Species

By Geo. M. Darrow, *U. S. Department of Agriculture,* and Geo. W. Dewey, *Oregon State College, Corvallis, Ore.*

CONSIDERABLE differences have been observed in the drought-resistance of strawberry varieties and species used in the cooperative breeding work of the U. S. Department of Agriculture and the Oregon State College at Corvallis, Oregon. In general, the Blakemore and Missionary in eastern States and the Ettersburg 121 in the Northwest are the most drought-resistant varieties, and *Fragaria chiloensis* and *F. cuneifolia* are the most drought-resistant species. Except possibly in Ettersburg 121 and *F. chiloensis* which have deep root systems, there are no gross morphological characteristics which may be correlated with drought-resistance. Most of the water loss of plants takes place through the stomata of the leaves. For this reason a study of the stomata was undertaken to determine whether differences in their position, number, morphology, or physiological activities might help to explain drought-resistance or susceptibility. Plakidas (2) has reported on the average number of stomata per square millimeter. He found a few stomata (5.5 per square millimeter) on the upper surface of the Klondike, one on the upper surface of the Howard 17, and none on the upper surface of any other variety. On the lower surface of strawberry leaves the number ranged from 234 to 305 per square millimeter.

Methods

The varieties and species used in these studies were Blakemore, Corvallis, Ettersburg 121, Marshall, selections of *F. chiloensis, F. vesca, californica* (*F. bracteata*), *F. cuneifolia, F. nilgerrensis,* and *F. virginiana,* and selected hybrids of *F. chiloensis* x Ettersburg 121 and x Marshall.

Plants in the field under irrigated and non-irrigated conditions, in pots in the greenhouse, and in topping experiments where the leaves had been cut off at the end of the harvest season and one and two months later, were available for study. Because of the long summer drought the non-irrigated field plants had wilted and many of the older leaves died. Moisture from a deep soil kept the plants alive. Horizontal and vertical paraffin sections of leaves of comparable age produced under drought, irrigation, and greenhouse conditions, were prepared for study.

In spite of abundant plant hairs and some difficulty in stripping, it was found possible to strip enough of the epidermis of the lower surface of the leaves for study. The percentage of opened stomata and the percentage of the opening were estimated. Only stomata estimated to be 10 per cent open were counted. Some of the better strips were stained and the size of the stomatal aperture measured and the number counted. Usually no attempt was made to count openings below 10 per cent. The most satisfactory stain for non-permanent

mounts was chloroiodide of zinc, made by dissolving potassium chlorate in water and adding to the solution crystals of zinc iodide until saturated. It was used with fresh material and with specimens run through a killing solution. The specimens were covered with the stain for 2 to 3 minutes, washed, and after 15 to 20 minutes they were satisfactory for study. The stain lasted for several hours but eventually spread to other tissues.

Number of Stomata

The number of stomata per square millimeter was determined by projecting the stripped surface under a microscope on to a square of paper of known area with a camera lucida, and locating each stoma on the square of paper. Four or more comparable records were used to get the averages. As given in Table I, Corvallis, Ettersburg 121, and *F. chiloensis 13C* have more stomata per square millimeter of leaf surface than have other varieties and species. The average number per square millimeter for Marshall was 275 for the base of the leaf, 309 for the tip, and 350 for the center not far from the mid-rib. As shown by Table I, field plants with relatively smaller leaves had more stomata per square millimeter than did greenhouse plants which were less exposed to air of low humidity. The field plants had somewhat more than did those studied by Plakidas. The range in number of stomata for all conditions was 200 to 350 for Marshall, 300 to 500 for Ettersburg 121, and 225 to 325 for *F. cuneifolia.*

Distribution of Stomata

Stomata were found on the under surface of the leaves, on the petioles, and once on the fruit of the strawberry. None were found on the upper leaf surface in the varieties studied. The portions of the lower surface having stomata are the spaces between the veins, the "vein islets." No stomata were found directly below the veins so that they occurred on about half of the lower surface. The stomata seemed to be closer together near the veins than toward the center of the vein islets. This might be expected, as the center of the vein

TABLE I—Average Number of Stomata per Square Millimeter of Leaf Surface of Strawberry Varieties and Species Growing in the Field and in the Greenhouse

Variety	For Field Plants	For Greenhouse Plants	Drought Resistance Estimated
Corvallis	389	320	2
Ettersburg 121	387	368	1
F. chiloensis selection 13C	358	—	1
Marshall (irrigated)	303	220	4
F. cuneifolia	—	303	1
F. virginiana	—	269	4
Ore. 115 (*F. chiloensis* x Marshall)	256	256	2
Missionary	—	245	2
F. chiloensis selection 5C	—	225	1

islets enlarges more than its edges after the leaf unfolds. The counts given are for areas having stomata. Their arrangement was very irregular both in relation to each other and to the epidermal cells. They were as close as one cell apart in places and several cells apart at others.

SIZE AND SHAPE OF THE STOMATA

The relative size of stomata of several varieties and species was obtained by measuring the length and breadth of 10 or more closed stomata. These records showed the following sizes as compared with those of Ettersburg 121, which were the largest:

Variety or Species	Relative Size of Stomata (Per cent)	Variety or Species	Relative Size of Stomata (Per cent)
Ettersburg 121	100	Marshall	77
F. chiloensis	99	*F. virginiana*	72
Corvallis	84	———	—

The stomata of *F. nilgerrensis* were approximately half the size of those of Ettersburg 121 while those of Aroma, Howard 17, Rockhill, Missionary, and *F. vesca californica (F. bracteata)* were noticeably smaller than those of Marshall. Slight differences in the size of the stomata on the different parts of the leaves were also observable.

The stomata of the Marshall as well as the apertures were more nearly circular in outline than those of the other varieties or species while those of Ettersburg 121 and *F. chiloensis* were more elongated, as shown in Fig. 1. In general the size and shape of the stomata were characteristic for each of the eight varieties and five species studied.

STRUCTURE OF STOMATA

In cross sections of the leaves the stomata of the strawberry are seen to be sunken within the leaf tissue. The stomata may even be so sunken that the outer surface of the guard cells is in line with the inner epidermal cell wall (Blakemore in Fig. 1). The epidermal cells tend to project over the guard cells, making a deep, narrow pit (Figs. 1-H and 1-K) which, compared with plants having stomata on the surface, slows up the movement of moisture especially in dry weather.

The position of the stomata in the leaf differs in the different species and varieties. The stomata of Blakemore, Corvallis, Ettersburg 121, Missionary, and *F. chiloensis* seemed to be sunken more than those of Marshall and *F. virginiana,* that of Blakemore being sunken most of those studied (Fig. 1-L). Some differences in their location within the same variety or species were apparent but were not definitely correlated with previous treatment. The guard cells of all varieties and species were heavily cutinized (Fig. 1-G).

STOMATAL MOVEMENTS

A difference in the speed with which the stomata of strawberries

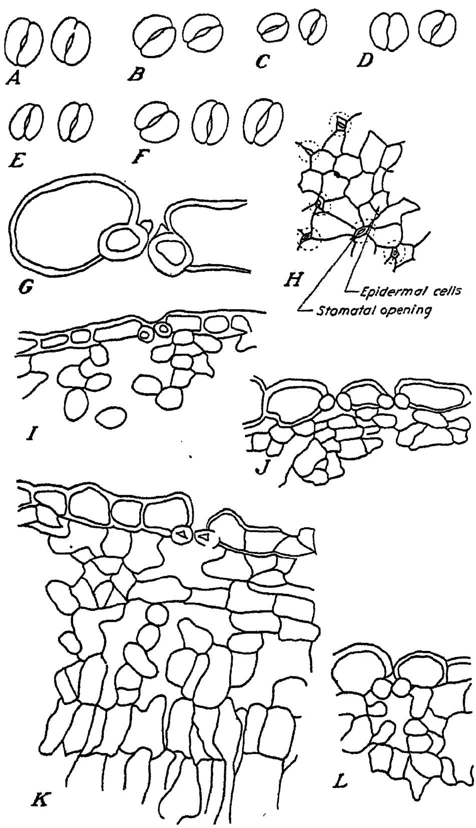

FIG. 1. (A–G) Drawings showing relative size and shape of stomata of varieties and species of strawberry. (A) *Fragaria chiloensis;* (B) *F. virginiana;* (C) *F. nilgerrensis;* (D) Marshall; (E) Howard 17; (F) No. 115 *F. chiloensis* x Ettersburg 121; (G) Vertical section of stoma of Corvallis.

(H). Lower surface of the leaf of Southland showing the narrow opening above the stomata made by the overhanging epidermal cells.

(I–L). Position of stomata in the strawberry leaf. (I) Slightly sunken stoma of *Fragaria virginiana* (6A); (J) slightly sunken stoma of Marshall (1B); (K) relatively deeply sunken stoma of *F. chiloensis* (7); (L) relatively deeply sunken stoma of Blakemore (3A).

react to changing conditions was observed. In one instance when leaves on plants in the field with most stomata wide open were watched under the microscope, after 5 minutes the stomata of *F. chiloensis* 5C were 50 per cent closed, while less than 5 per cent of those of O. S. C. 186 (*F. chiloensis* x Marshall) were closed. At the end of 15 minutes the stomata of *F. chiloensis* 5C were entirely closed while after half an hour those of O. S. C. 186 were not fully closed.

Under severe drought conditions during the latter part of July, stomata of Corvallis, Ettersburg 121, and *F. chiloensis* in an unirrigated field started to open about 7:00 a.m. By 8:30 to 9:00 not to exceed 10 per cent of the stomata had opened when a breeze starting up caused them to close immediately and they remained closed for the day. Under irrigation they remained open much longer. Just before applying water on July 31, stomata of Corvallis, Ettersburg 121, and Marshall began to open at 7:00 a.m. and by 9:00 a.m. the maximum number were open—Marshall, 80 per cent; Corvallis, 70 per cent; and Ettersburg, 121, 20 per cent. All had closed by 11:00 a.m. In contrast

to this on August 4 in the same field following irrigation, stomata of the Marshall were well opened at 8:00 a.m. and reached a maximum of 80 per cent at 9:00, closed to 25 per cent at 1:00 p.m., had opened to 50 per cent by 3:00 p.m., and at 5:00 p.m. were nearly closed. Stomata of Ettersburg 121 under irrigation followed the same general course of response as those of the Marshall but were not open as wide, especially in the afternoon.

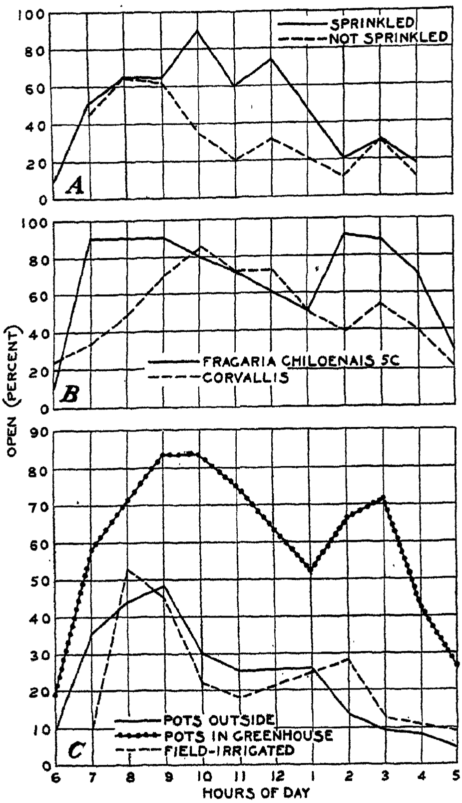

FIG. 2. A. Percentage of stomata open on sprinkled and non-sprinkled plants of Oregon 115 (*F. chiloensis* x Marshall) under irrigation at Corvallis, Ore., Aug. 13, 1931.
B. Percentage of stomata open on Corvallis and *F. chiloensis* 5C in the greenhouse at Corvallis, Ore., average Aug. 20, 21, and 25, 1931 records.
C. Response of the stomata of Corvallis strawberry plants under irrigation and in pots well watered inside and outside the greenhouse at Corvallis, Ore.

To study the effect of overhead sprinkling on stomata on a sunny day with low humidity, irrigated plants of Corvallis and of Oregon 115 (*F. chiloensis* x Marshall) were sprinkled every few minutes throughout the day. The response of the two varieties was similar. More of the stomata of the sprinkled plants opened, they opened wider and remained open longer than on unsprinkled plants, enabling the sprinkled plants to function more fully and longer than the unsprinkled plants (Fig. 2A). The stomata of the sprinkled plants, however, did not remain open as long as those of the unsprinkled irrigated plants on the cloudy days when observations were made.

Under greenhouse conditions the responses at first appeared inconsistent, as stomata of some plants were closed while those of others remained open for the entire day. However, when plants with stomata closed were well watered their response was similar to the others and consistent results were obtained. With limited root distribution in pots, extra

thorough watering is necessary for thorough wetting of the soil. For example, the stomata of one Marshall plant were closed when those of others were open. It was heavily watered and within an hour its stomata were opened and remained open the rest of the day. The stomata of *F. chiloensis* 13C and of *F. chiloensis* 5C were open in the greenhouse longer than those of any of the varieties or other species studied. The stomata of these two species began to open about 6:00 a.m., reached maximum opening between 8:00 and 9:00, and reached the maximum afternoon opening between 2:00 and 3:00 p.m. (Fig. 2). In comparison with out-of-door plants more stomata in the greenhouse were open wider than on plants outside (Fig. 2C).

Because of the response of the stomata of Marshall plants when not sufficiently watered, it was thought possible that stomatal closing and opening might be very rapid. However, although the stomata of any strawberry plant might be made to close by removing the plants from the greenhouse to the hot, dry, outside atmosphere or by turning an electric fan on the plants, under no condition did the stomata reopen the same day.

Stomatal Movement of Topped Plants

Under severe drought conditions observations were made on the opening of stomata of the varieties Ettersburg 121 and Marshall on non-irrigated plants, some of which were topped (leaves mowed) after the harvest season, others which were topped one and 2 months later, and still others which were not topped (check). The topped plants of both sorts had sent out new leaves, the untopped plants of Marshall had made a little new growth, while those of Ettersburg 121 had made no apparent new growth, since June at least. After several weeks without rain when the sky was cloudy throughout a day with little wind (August 5), stomata on leaves of untopped Ettersburg 121 opened slightly in the morning and not at all in the afternoon; those of untopped Marshall were well opened at 8:00 a.m., reaching a peak at 10:00 a.m., but were nearly all closed in the afternoon. In contrast, 80 per cent and 90 per cent of the stomata of topped plants of Marshall and of Ettersburg 121, respectively, were well opened at 8:00 and at 10:00 a.m. A second maximum opening occurred at 1:00 p.m., when about 10 per cent more were open than in the morning. Stomata on leaves of the topped Ettersburg 121 remained open longer than those of the topped Marshall. On August 6, which was clear with an afternoon breeze, most of the stomata (90 to 95 per cent) of the topped plants of both sorts and of the untopped Marshall were wide open by 9:00 a.m. and were entirely closed by 1:00 p.m. On August 12 the stomatal response was similar to that on August 6, but all were entirely closed by 10:00 a.m., while on August 18 a large part of the stomata remained well opened until after 1:00 p.m. (See graphs in Fig. 3.)

Discussion

Though the cultivated strawberry is derived from hybrids between *Fragaria virginiana*, a native of humid regions, and *F. chiloensis*, a native of a region of humid falls, winters, and springs, but dry sum-

mers, the stomata of cultivated varieties show adaptation to xerophytic conditions. The position of stomata in the selections of *F. virginiana* and of *F. chiloensis* examined is variable but in general less sunken in *F. virginiana* than in *F. chiloensis.* The known response of these species and of varieties having stomata in similar positions corresponds to their known drought resistance. *F. chiloensis,* Ettersburg 121, Corvallis, Blakemore, and Missionary are considered more drought-resistant than *F. virginiana* and Marshall and it seems possible that structure and position of stomata may be factors in drought-resistance of strawberries.

In number of stomata per unit area and in size of stomata, *F. chiloensis* exceeded *F. virginiana* by about 25 per cent, while in both respects Ettersburg 121, a variety having many of the characteristics of *F. chiloensis,* exceeded that species. Contrary to the general conclusions of Maximov (1), *F. chiloensis,* with larger and more numerous stomata, was seen to endure drought better than *F. virginiana.* The graphs in Fig. 2 indicate that the stomata of Ettersburg 121 are more sensitive to dry weather than are those of Marshall and that the stomata close more quickly than do the smaller, less numerous ones of Marshall. Under greenhouse conditions with lower light intensity, greater humidity, and ample soil moisture, stomata of *F. chiloensis* and Ettersburg 121 opened wider and remained open longer than did those of the Marshall. It would seem reasonable to assume, therefore, that under conditions of ample soil moisture, *F. chiloensis* and Ettersburg 121 would function more efficiently per unit area than would Marshall, and that under dry weather conditions Ettersburg 121 would endure drought better than Marshall. Possibly this may be one factor entering into the relative development of Marshall and Ettersburg 121 plants during the winter and early spring when humidity is high, the light is less intense than in summer, and soil moisture is ample. Though Marshall develops rapidly in the spring, Ettersburg 121 develops even faster. Thus, in the field at Corvallis, Oregon, new leaf growth on one-year-old plants up to June 8 during the humid spring was, for Marshall, 22 leaves with a total area of 1,871 square centi-

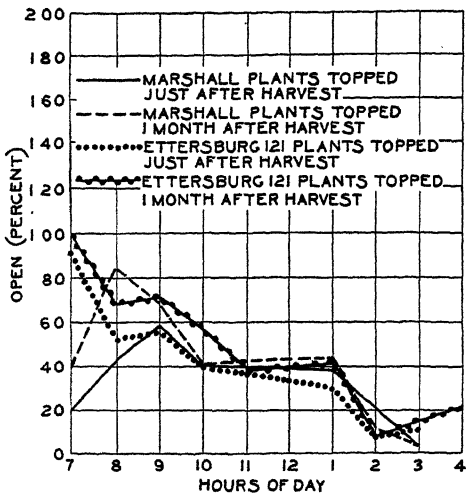

FIG. 3. Response of stomata of Marshall and Ettersburg 121 plants under severe drought conditions at Corvallis, Ore., Aug. 18, 1931. Above, plants topped 1 month after harvest; below, plants topped just after harvest.

meters and, for Ettersburg 121, 94 leaves with a total area of 5,235 square centimeters or nearly three times as much.

Summary

Stomata were found within the vein islets on the under surface of the strawberry leaf, none having been found directly below the veins. They numbered from 200 to 500 per square millimeter, Marshall having less than Corvallis or Ettersburg 121. The stomata of Ettersburg 121 were larger than those of Corvallis and Marshall and those of *Fragaria chiloensis* larger than those of *F. virginiana* and *F. nilgerrensis*. The stomata of Blakemore, Corvallis, Ettersburg 121, Missionary, and *F. chiloensis* are more sunken than those of Marshall and *F. virginiana*.

Under drought conditions, stomata of Marshall plants opened very slightly for a short time in the early morning while in contrast on irrigated plants about 80 per cent had opened by 9:00 a.m.; 25 per cent remained open at 1:00 p.m.; 50 per cent were open at 3:00 p.m., and nearly all were closed at 5:00 p.m. Under greenhouse conditions, stomata of *Fragaria chiloensis* opened more than those of several varieties. Under field conditions marked differences in the speed of reaction of the stomata of different varieties was observed. Stomata of sprinkled plants opened more and remained open longer than those of unsprinkled plants. Stomata of irrigated field plants responded much like those of well watered potted plants, fewer of them opening than on plants in the more humid greenhouse where the light intensity is less than outside. Under drought conditions the stomata of topped plants opened more and stayed open much longer than those of untopped plants, and those of younger leaves on recently topped plants opened more widely than those of older leaves on untopped plants.

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The Effect of Carbohydrate and of Nitrogen Deficiency upon the Male Sex Cells in the Tomato

By F. S. Howlett, *Experiment Station, Wooster, O.*

Abstract

The complete paper will be published elsewhere.

THE experiments reported were designed to determine the effect of carbohydrate and of nitrogen deficiency upon the male sex cells in the tomato. The carbohydrate and nitrogen contents were altered by varying seasonal day lengths and by supplemental illumination which extended the light period.

A cytological examination was made of chromosome behavior at the stages leading up to and including the formation of mature pollen grains. Pollen grains were tested for viability on agar media and on the stigmas of hand pollinated flowers and in addition were stained with various reagents during the entire course of the investigation.

Carbohydrate deficiency:—The size attained by the flowers which failed to reach anthesis on the fall and winter-grown plants depended upon the degree of carbohydrate deficiency. Under very severe carbohydrate deficiency even the reduction divisions were not reached and the flowers abscissed while very small. Under less severe conditions some flowers reached anthesis even though the locules contained only degenerated microspores or sterile pollen grains.

In these flowers which reached anthesis under the severely deficient conditions the reduction divisions had usually proceeded normally even though no viable pollen grains were produced. Commonly the entire contents of the anthers were so affected. With increasing carbohydrate content an increasing proportion of microspores became functional and an increasing proportion of viable pollen grains was produced. In the vigorously vegetative plants grown in spring and summer the flowers of the first two clusters showed an appreciable proportion of morphologically perfect but non-germinable grains. Such plants were characterized by a condition of mild carbohydrate deficiency in consequence of their very rapid growth which is associated with abundant amino acid and protein formation.

The degeneration of microspores occurred at any stage during the course of their development following the second meiotic division. Likewise pollen sterility was produced when carbohydrates became deficient during the period just previous to anthesis.

Nitrogen deficiency:—As opposed to the situation with carbohydrate deficient plants the formation and development of the male sex cells under nitrogen deficiency showed a decided regularity and stability. A very large proportion of the microspores were functional and the greater proportion of the pollen grains were germinable.

Nitrogen deficiency when very severe did result in some microspore degeneration and pollen sterility but even in the third and last cluster developed on the nitrogen deficient plants a considerable proportion of the grains were germinable.

General conclusions:—The full significance of the different response of the male organs and sex cells to carbohydrate as opposed to nitrogen deficiency cannot be grasped without consideration of the corresponding reaction of the female organs and sex cells to the same deficiencies. Data are available which could not be presented in this paper which show that the female organs and sex cells are relatively little affected by carbohydrate deficiency but are decidedly repressed in their development by nitrogen deficiency.

When the reverse response of the male and female organs to nitrogen and carbohydrate deficiency is analyzed it becomes evident that ultimately the problem deals with the factors which result in sex suppression and in sex reversal in plants. *Carbohydrate* deficiency has thus resulted in the suppression of the male organs or has induced "femaleness." On the other hand, *nitrogen* deficiency has resulted in the suppression of the corresponding female organs. In addition the literature on the subject would indicate that this opposite response to the carbohydrate and nitrogen deficiencies is not confined to hermaphroditic and monoecious plants but is also evident in some dioecious species.

Thus carbohydrate and nitrogen deficiencies achieve importance as limiting factors in the sexual expression of certain seed plants and horticultural practice, designed to maintain a sufficiently high content of these substances for flower development, represents the primary means of preventing unfavorable changes in sex expression.

How Far Should Sweet Corn Grown for Seed be Planted from Other Corn to Prevent Contamination?[1]

By E. S. HABER, *Iowa State College, Ames, Ia.*

THE production of seed of varieties of sweet corn and the production of hybrid sweet corn seed in detasseling blocks requires isolation from other strains of corn so that the seed stock will be reasonably free from contamination with other corn. Protandry, which is common in most varieties of corn, helps to prevent self-pollination. Since wind and gravity are the chief agencies in pollen dissemination, cross-pollination is the rule. Self-pollination occurs less than 1 per cent of the time.

The increased demand for hybrid sweet corn seed has induced numerous growers to attempt to produce hybrid seed. Because of the greater number of hybrids offered for sale as well as a great many stocks of seed of a popular hybrid, such as Golden Cross Bantam, this has necessitated the certification of hybrid sweet corn by a competent agency to protect careful seedsmen. For certification in Iowa, "when seed is produced in an isolated plot, the plot must be so located that the female parent is not less than 40 rods from other sweet corn which sheds pollen at approximately the same time (except for the pollinating parent). This distance may be modified by the size of the crossing fields and by the planting of border rows of male parent." These rules for isolation are not based on any definite experimental work but were arbitrarily made from the experience and judgment of a number of individuals.

In 1934 the hybrid sweet corn yield tests of the Vegetable Crops Subsection were planned to determine the degree of contamination from cross-pollination which may occur when planted close to other corn. The field was planted with hybrid and open-pollinated strains of Evergreen and Country Gentleman sweet corn. The hills were check-rowed 3½ feet apart, with each hybrid and variety planted in two rows 10 hills long and replicated eight times in the field. Each row running north and south was 90 hills long and the row included nine different hybrids and varieties. The total area planted was about 5 acres. The blooming dates for the various hybrids and varieties covered a period of about 12 days.

On the east side of the field seed corn was planted segregating in a 1:1 ratio for sweet and starchy kernels. From 50 to 75 per cent of the plants produced pollen which would cause purple aleurone to be produced when pollinating the sweet corn hybrids and varieties planted in the yield tests. About ¾ acre of this purple aleurone material was planted; the rows running north and south were the same length as the yield test plot rows. The two types of corn were adjacent to each other with no distance between other than the row for cultivation. To the casual reader the use of a variety such as Black Mexican might have been a better choice, since 100 per cent of the

[1]Journal Paper No. J-210 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 293.

pollen would bear the factors for purple aleurone. Black Mexican is not nearly so vigorous or as tall as the material used and blooms considerably earlier than most of the hybrids. The principal source of contamination to sweet corn in the corn-belt is field corn, which is more vigorous and has more viable pollen in an unfavorable season, which explains the choice of the above corn as a source of contamination.

On September 1, husks were stripped back on the ears in the hybrid yield test plots and a rough count made of the kernels present containing purple aleurone. Not all of the ears of the various hybrids were well-filled due to drouth and heat. Such ears were not included in the records. Some of the hybrid ears were well-filled but no purple kernels were present. It was assumed that these hybrids did not silk at the same time that the purple aleurone corn was shedding pollen and these ears were not included in the records. Plants producing ears containing purple kernels must have silked at the time the purple aleurone producing plants were shedding pollen.

In the following table the amount of contamination is presented. Row 1 is the first row adjacent to the purple aleurone producing plants, which was at 3½ feet distance. The percentage of heavy contamination included well-filled ears which had more than five purple kernels present. The percentage of light contamination included well-filled ears containing from one to five purple kernels.

TABLE I—Percentage of Ears Contaminated

Row No.	No. Ears Examined	Per cent Heavy Contamination	Per cent Light Contamination
1	150	5.0	7.0
2	150	6.0	11.0
3	150	0.0	7.5
4	150	0.0	8.5
5	90	28.0	11.0
6	90	28.0	13.0
7	30	10.0	20.0
8	30	3.0	30.0
9	30	3.0	6.0
11	90	15.0	6.0
12	90	15.0	11.0
13	40	5.0	5.0
14	40	10.0	7.5
15	90	14.5	14.5
16	90	5.5	24.5
20	30	0.0	16.5
25	60	5.5	11.0
30	60	3.0	3.5
35	60	3.5	23.5
40	30	0.0	16.5
45	30	0.0	23.0
50	30	0.0	10.0
55	30	0.0	10.0
60	60	0.0	5.0
70	30	0.0	10.0
80	90	0.0	6.5
90	30	0.0	5.5

After the 35th row, or greater than a distance of 7 rods, no ears were found which were heavily contaminated. Light contamination extended to the 90th row (18 rods). Between the 90th and 115th rows an occasional purple kernel was found, but this contamination was less than 1 per cent in any row.

Perhaps there would have been less contamination if all of the sweet corn in the test plots had been shedding pollen at the same time, which would have given a preponderance of sweet corn pollen. On the other hand, in detasseling blocks the male and female parents are planted one or two rows of male to four rows of female; the female rows of course are detasseled. Under such conditions there probably would not be any more if as much pollen present as in this case, so that one could expect at least as much contamination from other corn if it were planted as close. Also, only 50 to 75 per cent of the plants produced pollen causing purple aleurone to form; therefore the contamination percentages might have been greater if 100 per cent of the plants had produced pollen which would cause detectable contamination in the sweet corn. Prevailing winds, likewise, would have some effect on the degree of contamination. The prevailing winds during the blooming period at Ames are usually southerly to westly winds. The source of contamination in this experiment was on the east side; possibly the pollen would have contaminated corn at a greater distance if the source of contamination had been on the south or west side of the field.

In the Iowa rules for certification, when the field is 9 acres or less in extent it is necessary to have 12 border rows of male parent on the sides of the field exposed to contamination when the source of contamination is at a distance of 10 rods. At such distance in this experiment no heavy contamination occurred, but 5 per cent light contamination did occur at this distance.

The title of this paper is presented in the form of a question: "How far should sweet corn grown for seed be planted from other corn to prevent contamination?" Sufficient data have not been presented to answer the question definitely, but under the conditions of this experiment some idea may be obtained as to the degree of contamination to be expected. Since experimental data are not available to guide the seedsmen or grower, this is offered as a preliminary statement and is not to be judged as a finished piece of work.

Summary

Corn producing pollen containing the factors for producing purple aleurone was planted adjacent to Evergreen and Country Gentleman hybrids and varieties. The degree of contamination varied with the distance from the source of contamination. Under the conditions of this experiment, at a distance greater than 7 rods there was no longer heavy contamination. At a distance greater than 18 rods there was no longer light contamination, although a contaminated kernel was found occasionally at a distance of 23 rods but amounted to less than 1 per cent contamination.

Corn-Earworm Resistance in Maize Varieties at Davis, California, 1934

By CHARLES F. POOLE, *University of California, Davis, Calif.*

THE chief limiting factor in growing sweet corn in California is the corn earworm, *Heliothis obsoleta*, Fab. As a preliminary step in developing several sweet-corn varieties adapted for local usage, the California Experiment Station, in the past year, tested 39 varieties from all parts of the country. Of these, 29 were sweet-corn types, five were starchy dent types used in some sections as roasting corn, and five were field varieties known to be somewhat resistant to the earworm. The seed was obtained through the courtesy of three seed companies and three experiment stations.

The test aimed to carry each of the varieties in 60 square foot plots of eight replications, planted in two sections 1 month apart in order to observe any possible seasonal differences in insect attack or plant response. The first four replications were planted April 18; the second four, May 26. In a few varieties insufficient seed was obtained to plant eight replications, and three inbred lines of King Phillip were received too late for inclusion in the plot planted April 18.

Varieties were measured or classified under 13 categories, most of which were made in the milk or roasting-ear stage of development. Of the 13 categories, the most important from an economic viewpoint is Percentage of Marketable Ears at the milk stage. Accordingly, the 39 varieties were ranked in the order of their yield of marketable ears, which is here defined as perfect or having only slight tip injuries. The group of items next in importance was the combined data on types of earworm injury, comprising the following categories, with numerical values accompanying: (A) Ears free from attack,—5; (B) ears attacked in silk only,—4; (C) ears attacked in silk and tip only,—3; (D) ears attacked beyond tip but marketable,—2; and (E) ears damaged beyond marketability,—1.

This method of scoring permitted calculation of a mean value, the Injury Index, and also permitted correlation studies with other quantitative measurements. A variety with an index of 5.0 would have been one containing no damaged ears, whereas, at the other extreme, a variety with an index of 1.0 would have been one with no marketable ears. The magnitude of the index was valuable in determining the relative promise of a variety for further improvement, aside from its economic usefulness. Hence the two categories of "Per cent Marketable," to indicate agricultural value, and "Injury Index," to indicate breeding value, were of prime importance in this first sweet-corn variety test conducted by the California Experiment Station.

The remaining items employed were of secondary importance and merely showed features to be considered in choosing varieties with character combinations preferred in different localities, such as silage possibilities, relative earliness, and yielding ability.

The data presented in Table I list the varieties in the order of percentage of ears marketable, with the 29 sweet corns first and the

TABLE I—SWEET CORN VARIETY TEST, DAVIS, CALIFORNIA 1934. PLANTED APRIL 18 AND MAY 26

Variety	No. of Ears	Days to First Tassel		Days to First Silk		Height (Cm)	Weight Husked Ears (Gms)	Number of Ears 20 Hills	Length of Husked Ears (Cm)	Husk Projection Past Tip (Cm)	Injury Index	Per cent Marketable
		4/18	5/26	4/18	5/26							
1 Oregon Evergreen	61	66	62	70	67	178.2	127.2	28	17.9	9.4	3.0	82.0
2 Papago	80	72	66	73	69	242.4	93.0	28	19.6	7.0	2.6	81.3
3 Florida 191 (No. 1)	26	72	62	75	68	208.4	94.5	19	17.3	9.3	2.8	76.9
4 Surecropper Sugar	80	75	66	78	69	236.2	128.6	26	16.7	7.6	2.4	76.3
5 Honey June	80	73	66	79	74	241.2	131.0	30	16.0	6.9	2.4	76.3
6 Florida 191 (No. 2)	71	71	62	72	67	223.7	99.6	25	18.5	9.3	2.7	73.2
7 Oregon Evergreen (No. 2)	80	66	61	72	68	175.9	125.7	33	18.0	9.1	2.1	61.3
8 Alameda Sweet	56	58	49	62	55	132.2	118.9	24	14.5	7.2	2.3	58.9
9 Early Alameda	80	58	50	60	54	139.9	113.1	28	14.3	6.5	2.0	53.8
10 Country Gentleman Hyb	80	67	59	71	66	193.7	118.3	28	17.1	9.7	2.1	53.8
11 Bantam Evergreen	65	63	56	69	61	194.3	106.6	20	16.8	9.9	2.1	49.2
12 Golden Cross Bantam	80	61	52	64	59	149.3	108.8	35	17.3	6.4	1.6	46.3
13 Stowell's Evergreen Hyb	77	67	59	71	68	189.5	119.6	21	17.0	10.7	1.8	45.5
14 Hoopeston Top Cross	80	61	50	63	54	164.4	103.5	31	16.7	7.1	1.8	42.5
15 Asgrow Top Cross	80	58	51	65	60	173.6	124.0	32	16.5	7.7	1.5	40.0
16 Howling Mob	80	59	50	59	53	160.8	148.3	32	16.4	6.4	1.8	38.8
17 Country Gentleman	45	71	61	74	73	162.9	101.0	20	16.2	8.0	1.8	37.8
18 Narrow Grain Hybrid	80	67	61	72	67	188.8	134.9	22	15.7	8.7	1.6	36.3
19 Burbank Bantam	80	58	49	62	55	149.5	105.3	24	14.6	8.0	1.7	36.3
20 Golden Bantam (No. 1)	80	55	49	56	51	153.3	67.0	28	14.2	8.6	1.8	35.0
21 Golden Bantam (No. 2)	80	56	48	59	50	145.2	81.0	25	15.3	8.3	1.7	35.0
22 Minnesota Giant	70	69	51	64	60	142.3	109.6	24	16.6	8.2	1.7	32.9
23 Early Golden	71	60	50	64	55	156.4	116.9	18	14.2	8.0	1.8	28.2
24 Clark's Early Evergreen	74	63	56	67	62	176.0	108.4	24	15.7	9.2	1.8	27.0
25 Golden Sunshine	49	51	42	52	45	122.1	128.1	24	14.1	4.4	1.4	22.4

26 Spanish Gold	80	52	44	51	42	141.1	75.3	31	12.4	8.3	1.4	21.3
27 Golden Early Market	80	51	43	52	47	122.3	110.8	24	14.1	4.8	1.5	20.0
28 Early Surprise	80	51	44	53	47	138.4	138.2	27	14.7	5.3	1.3	16.3
29 Purdue Inbred 1339	53	64	53	68	60	129.9	89.4	20	15.7	7.5	1.2	9.4
A* King Phillip—54	2	—	70	—	80	132.3	119.0	12	18.6	12.7	4.5	100.0
B Mexican June	80	85	80	87	86	273.4	236.3	28	21.8	4.4	2.3	87.5
C King Phillip—80	28	—	67	—	72	198.8	176.6	30	23.2	6.8	2.7	82.1
D Truckers' Favorite	80	64	58	67	61	226.4	177.0	24	20.5	6.9	2.5	80.0
E Cuban Yellow Flint	31	86	—	90	—	246.7	79.1	16	17.2	9.5	2.7	77.4
F Dubose	26	81	—	86	—	238.5	81.8	16	16.6	12.4	3.0	73.1
G Snowflake	52	80	69	86	79	280.0	125.9	29	18.3	7.3	2.2	57.7
H Adam's Large Early	80	56	48	58	49	170.0	140.9	29	15.0	6.4	1.8	52.5
I Adams Ext. Early Dwarf	80	53	42	54	44	158.2	130.2	29	14.3	4.2	1.8	48.8
J King Phillip—90	5	—	64	—	68	125.4	129.6	8	17.9	4.5	1.8	40.0

*Lettered varieties are field corn.

starchy corns at the bottom. The table shows the total measurements combined for the two plantings of April 18 and May 26, except in the case of "Days to First Tassel" and "Days to First Silk" where the varieties in the May plot all matured in fewer days than those in the April plot. The only other category in which consistent differences occurred between the two plantings was in earworm injury, wherein more severe injury was observed in the May plantings for all varieties except Surecropper Sugar, Honey June, and Mexican June, which strangely showed less damage in the May plantings. For other categories, differences between the two plots were not consistently in any one direction; therefore the mean value shown in the table is for the combined total.

As the table shows, under the conditions of this test ten sweet corn varieties marketed 50 per cent or better, and the Injury Index was 2.0 or better. Further analysis reveals a significant positive correlation of 0.61 ± 0.07 existing between number of days to maturity and Injury Index, as well as 0.69 ± 0.06 between height and Injury Index, indicating that the tallest varieties are the latest maturing and that tallest and latest are the freest from injury. This is interesting in connection with a previous observation by Collins and Kempton (1), namely, that later varieties usually have more numerous husks than earlier varieties and are therefore less subject to earworm injury.

In the hope that a morphological character might be used to indicate in advance those ears free from caterpillar injury, the projection of husk past the tip was correlated with the five types of insect injury. The method of scoring these injury types would consequently produce a positive coefficient if projection is correlated with injury, whereas in the study of Collins and Kempton (1) the correlation of degree of damage with length of projection gave a negative coefficient. In the May plot, therefore, 36 of the varieties in which more than five ears were harvested were correlated by Harris's crude score formula for these two variables. Finally all data were combined in one calculation for 1,142 plants, giving a positive coefficient, of no importance, of $r = 0.14 \pm 0.020$, for the total intra-variety correlation. Of the 36 varieties studied individually, all degrees of negative and positive correlations were derived, only six of which exhibited a coefficient exceeding $+0.32$, which Fisher gives as the minimum coefficient for significance in populations of 40 observations. The six varieties involved were King Phillip 80, King Phillip 90, Papago, Narrow Grain Hybrid, Florida 191 (No. 2), and Clark's Early Evergreen. To some extent this is at variance with Collins and Kempton's (1) results, in which a coefficient of -0.71 ± 0.06 was obtained by inter-variety correlation whereas our coefficient obtained with the correlation of variety means (see Table I) is 0.25 ± 0.11, very little different from the 0.14 ± 0.02 for intra-variety correlation. Some varieties, notably Mexican June, even showed less injury with shorter projections. Evidently then, such genetic factors as are responsible for the observed freedom from injury are only casually associated with husk projection; the real factors conferring resistance are as yet undetermined, but are very likely some chemical compound or the tightness and number of husks.

The only remaining correlation evident at a glance from Table I is between length of husked ears and marketability. In other words the most successful varieties are also the longest eared varieties. This is true because the best yielding varieties in this test are field varieties like King Phillip, Mexican June, and Truckers' Favorite, or sweet corn types like Honey June, Surecropper Sugar, and Florida 191 which have lately been derived from field corn varieties. The original field corns of the south were unconsciously selected by man from the best plants which through natural selection were adapted to such regions. Vigor, yield, and earworm resistance were features of such adaptation. On the other hand, the fact that Alameda Sweet, Early Alameda, and some of the Prolific varieties from the Gulf States are also resistant, but are not necessarily tall, long lived, or long eared, would suggest that resistance can readily be combined in the typical northern sweet corn complex of growth factors without changing the outward constitution.

Each of the preferred sweet corns is a variety that has been selected, naturally or artificially, for a region with problems similar to those found in California, namely, Arizona, Texas, or Florida. Of the two Texas varieties, Surecropper Sugar and Honey June, sufficient seed was furnished to permit planting a small lot in cooperation with a farmer in Santa Cruz, a locality having somewhat different climate from Davis yet likewise bothered with earworms. The cooperator harvested the two varieties along with an improved type of Golden Bantam planted as a check, with the result that he sold at the roadside 99.6 per cent of his Surecropper Sugar for 35 cents a dozen, 98.5 per cent of his Honey June for 35 cents a dozen, and 79.7 per cent of his improved Golden Bantam for 20 cents a dozen.

This paper merely constitutes a preliminary report on the more outstanding features of this variety test. A more detailed study is in progress.

In conclusion, this 1934 variety test indicated that six sweet corn types: Oregon Evergreen, Papago, Florida 191, Surecropper Sugar, Honey June, and Alameda (three of which occur in duplicate), and four field types, Mexican June, King Phillip 80, Truckers' Favorite, and Snowflake show sufficient promise to be used in developing a number of locally adapted superior sweet-corn varieties. Varieties planted in May are more injured by earworms and mature more rapidly than the same varieties planted in April. Taller, later-maturing, and longer-eared varieties are less susceptible to earworm attack. Degree of husk projection is apparently not generally associated with protection from earworm, although in six out of 39 varieties an apparently significant correlation was observed.

Literature Cited

1. Collins, G. N., and Kempton, J. H. Breeding sweet corn resistant to the corn earworm. Jour. Agr. Res. 11:549–572. 1917.

Is Resistance to Bacterial Wilt in Sweet Corn Heritable?[1]

By C. H. MAHONEY and J. H. MUNCIE, *Michigan State College, East Lansing, Mich.*

BACTERIAL wilt or Stewart's Disease has caused extensive damage to commercial plantings of early sweet corn in Michigan, and the development of early resistant varieties would be of great practical value to the vegetable industry. The first logical step in a plant breeding program of this nature is to determine whether there is heritable resistance to wilt, and if so, how resistance is manifested in the plant.

Many plant breeders have assumed that resistance is inherited in simple Mendelian fashion. Clinton and Singleton (1) state that it is possible by inoculation tests to isolate strains immune to wilt. It is questionable whether the problem is as simple as these workers intimate. Is resistance due to specific genes, as is Fusarium resistance in crucifers, or is resistance correlated with growth rate, size of plant, vigor, number and size of vascular bundles, or other morphological and anatomical characters? In other words, what is resistance and how is it manifested? Is so-called resistance, in reality, tolerance of the disease or disease escape?

In order to obtain answers or partial answers to these questions, fairly extensive plots were planted at the Corn Borer station in Monroe County and on the station grounds at East Lansing in 1933. There were 99 plots and 34 check plots at Monroe and 130 plots were planted at East Lansing. The standard commercial open-pollinated varieties, varieties and strains which have been classed by other investigators as resistant, and Early Bantam, Golden Bantam, and Whipple's Yellow inbreds, together with a large number of hybrid corns, were included in the tests. Seventy of these strains were tested in the greenhouse in the spring of 1933 to determine the percentage of seed-borne wilt. These tests included growing 50-kernel samples of the various corns, and counting resultant seedlings showing evidence of wilt infection. In addition, isolations were made from suspected seedlings showing water-soaked areas in the leaf, and the isolate compared culturally and pathogenically with known cultures of *Phytomonas Stewarti*. Three field readings were made at East Lansing and two at Monroe. All plants were counted which showed characteristic wilt symptoms, such as striping, water-soaked leaf lesions, or bacterial ooze in the bundles. Forty-nine progenies were planted in 30-hill triplicates in 1934. The wilt readings this season were made for each strain at the time the ears reached edible maturity. All plots, except F_2 and F_4 inbreds, were fully harvested and the average maturity date was calculated from the harvest frequencies. The data on the 1933 plantings are given in Table I.

[1]Journal Article No. 199 (n. s.) from the Michigan Agricultural Experiment Station.

TABLE I—WILT READINGS, GERMINATION, AND HARVEST DATA FOR SWEET CORNS GROWN IN 1933

Variety	Source Key No.[1]	Per cent wilt			No. Plants	Marketable ears per acre. Thousands	Greenhouse		Average No. of days to maturity
		6/20	7/20	8/10			Germination per cent	Per cent wilt	
Commercial Yellow Varieties									
Golden Gem.....	11	21.4	91.7	100	26	4	88	15.9	59
Golden Gem.....	8	15.8	91.4	100	24	4	96	6.2	62
Spanish Gold....	4	45.4	50.0	100	10	7	38	36.8	64
Spanish Gold....	8	14.3	62.1	88.5	26	10	84	28.5	64
Spanish Gold....	6	21.4	46.4	92.6	27	11	68	29.4	66
G. Early Market.	2	7.7	83.3	100	14	4	66	36.3	67
Golden Bantam.	5	41.2	55.2	76.3	38	14	84	28.5	68
Yellow Bantam..	3	26.0	53.3	80.5	41	14	—	—	68
E. Early Bantam	12	21.6	28.1	96.4	28	18	94	17.0	69
Golden E. Market	1	27.8	58.6	82.7	29	5	92	10.8	69
Banting........	11	20.0	45.8	82.1	28	11	78	10.2	69
The Burpee.....	2	28.6	55.0	100	20	9	56	10.7	70
Sunshine........	11	22.2	94.7	91.6	12	6	86	16.2	70
Sunshine........	2	15.6	46.7	63.9	36	10	84	4.7	72
Sunshine........	5	18.5	69.2	78.6	28	7	62	35.4	72
Carmel Golden..	5	17.4	42.8	53.8	26	11	72	16.6	72
Golden Standard.	5	8.8	48.8	56.4	39	7	88	22.7	72
Golden Crosby..	1	33.3	25.0	61.9	21	10	82	9.7	72
Sunshine........	13	6.7	46.4	63.9	33	15	76	13.1	73
Golden Bantam.	11	7.3	65.0	57.5	40	15	94	25.5	74
Bardens W. Bantam..........	1	15.8	18.4	34.5	55	19	92	8.6	77
Bardens W. Bantam..........	13	20.0	24.1	56.4	39	17	72	16.6	77
The Burbank....	2	27.3	25.9	56.0	25	12	68	8.8	78
Gold Coin.......	2	24.5	23.8	54.8	44	9	86	30.2	78
Sweet Orange....	2	33.3	57.1	60.1	20	13	32	31.2	78
Imp. Golden Bantam..........	1	—	23.5	56.7	37	17	92	17.4	80
Bantam Evergreen.........	5	16.7	26.7	23.5	17	16	86	25.5	81
Purdue Bantam.	8	10.0	4.2	21.9	32	17	78	12.8	82
Purdue Bantam.	10	23.7	10.0	35.1	37	17	78	17.9	83
Golden Giant....	2	32.5	22.9	44.4	36	17	72	16.6	83
Purdue 51.......	10	64.7	52.9	58.0	31	8	74	18.9	86
Hybrid Corns									
E. E. Bantam X1339........	7	26.2	45.9	66.7	39	24	—	—	72
Gold. Bantam X40..........	7	50.0	11.5	60.0	35	18	—	—	73
Chap. Bantam X8...........	7	11.4	18.2	33.3	36	20	—	—	74
45X1339........	7	17.1	22.5	37.5	40	22	—	—	74
40X1339........	7	3.9	16.2	30.0	50	24	—	—	76
8X1339.........	7	9.0	16.7	21.0	38	18	84	9.5	76
Hyb. 1804......	7	34.5	65.4	82.7	29	13.6	—	—	76
Top Cross Bantam..........	8	41.2	41.7	46.4	28	15	92	4.3	76
Top Cross Bantam..........	1	25.0	22.8	27.3	44	17	78	2.5	78

TABLE I—*Continued*

Variety	Source Key No.[1]	Per cent wilt 6/20	Per cent wilt 7/20	Per cent wilt 8/10	No. Plants	Marketable ears per acre. Thousands	Greenhouse: Germination per cent	Greenhouse: Per cent wilt	Average No. of days to maturity
Hybrid Corns									
Golden Cross Bantam	4	23.4	28.6	44.4	45	22	93	17.8	79
Golden Cross Bantam	1	20.0	29.4	31.4	51	19	98	6.1	79
Golden Cross Bantam	8	—	23.8	36.5	52	23	90	8.8	79
Golden Cross Bantam	10	12.7	27.1	34.0	50	24	—	—	79
Hyb. 1857	7	21.3	24.9	44.1	43	14	—	—	79
6X1339	7	12.5	17.2	12.9	31	14	—	—	79
28X45	7	26.0	12.0	36.7	60	22	—	—	79
Golden Bantam X 51	7	8.7	15.2	32.7	49	22	—	—	79
69X6	7	16.0	17.5	26.7	45	18	—	—	80
2X1339	7	11.6	7.7	16.3	43	18	—	—	80
29X1	7	39.9	11.1	15.6	48	22	—	—	80
Hyb. 1876	7	39.5	47.2	57.6	33	9	—	—	81
28X69	7	20.4	8.5	38.6	44	19	—	—	81
28X1339	7	34.1	31.6	50.0	36	15	100	2.0	81
Bantam Evergreen hyb. N8X15	1	3.8	16.0	19.3	31	12	66	30.3	82
73X1334	7	45.2	27.0	22.5	40	20	—	—	82
51X28	7	25.5	25.0	29.8	57	24	—	—	83
Narrow grain hyb. D63X26	1	13.7	8.6	21.3	47	10	86	25.5	84
7X45	7	18.0	22.5	24.4	41	15	—	—	84
123XJones Evergreen	7	9.3	5.3	4.8	42	19	—	—	85
1394X917	7	31.0	22.9	23.7	59	20	—	—	87
Narrow Grain Hybrid	1	11.1	19.5	30.2	43	14	98	2.0	88
I-20X5848	7	29.0	37.6	36.5	44	19	—	—	88
Stow. Evergreen Hyb. D63X50	1	10.0	20.6	13.6	44	10	90	20.0	89
Stow. Evergreen Hybrid D14X15	1	11.4	9.7	10.2	39	15	86	6.9	89
1445X908	7	5.6	20.8	10.3	58	22	—	—	89
917X1445	7	—	26.3	34.0	47	19	—	—	89
917X1610	7	27.5	29.4	31.5	54	17	—	—	90
917X Country Gent	7	30.2	24.4	31.0	58	10	—	—	90
908X1621	7	3.4	6.0	5.3	57	17	—	—	91
1394X1445	7	1.6	13.7	18.0	61	20	—	—	92
Commercial White Varieties									
E. Pickaninny	11	23.4	71.4	88.4	43	10	98	12.2	62
Nuetta	11	19.3	69.6	95.6	23	4	82	4.8	66
Alpha	5	16.7	62.5	87.5	40	5	84	14.2	67
Crosby	3	75.7	84.6	83.9	31	4	—	—	67
E. Surprise	1	—	70.0	71.4	28	7	86	2.2	68

TABLE I—*Continued*

Variety	Source Key No.[1]	Per cent wilt 6/20	Per cent wilt 7/20	Per cent wilt 8/10	No. Plants	Marketable ears per acre. Thousands	Greenhouse Germination per cent	Greenhouse Per cent wilt	No. of days to maturity
				Commercial White Varieties					
E. June.........	11	17.2	41.4	90.0	40	11	92	8.7	70
Imp. E. Dakota.	11	24.4	36.4	38.1	34	12	86	9.3	71
E. Sweet........	5	60.0	73.3	47.4	19	14	86	6.9	75
Alameda Sweet..	5	16.7	25.5	45.0	40	10	94	21.2	78
E. Evergreen....	5	16.7	26.1	29.6	27	13	66	39.3	81
Redgreen.......	4	—	13.3	37.0	27	14	56	17.8	84
Stowells Evergreen.........	5	11.1	18.5	28.6	35	15	88	29.5	86
Oregon Evergreen.........	5	10.8	21.9	15.8	38	13	84	14.6	88
Country Gent...	5	25.0	17.2	2.9	34	19	60	16.6	93
				Golden Bantam First Generation Selfs					
331234 F_1.......	9	30.8	24.1	52.8	34	14	100	11.5	76
331231 F_1.......	9	12.2	23.4	38.9	54	13	100	11.5	77
331232 F_1.......	9	7.7	0	57.1	28	18	100	21.8	77
331224 F_1.......	9	2.5	25.0	36.9	46	11	—	—	78
331225 F_1.......	9	—	33.0	50.0	32	14	100	25.0	78
331235 F_1.......	9	13.5	16.7	46.3	41	14	100	12.2	78
331233 F_1.......	9	6.2	22.9	25.5	47	12	100	14.0	81

[1]1. Associated Seed Growers, New Haven, Conn.
2. W. Atlee Burpee, Philadelphia, Pa.
3. Burnham and Morrill, Portland, Me.
4. Conn. Agr'l Expt. Station, New Haven, Conn.
5. Ferry-Morse Seed Co., Detroit, Mich.
6. Harris Seed Co., Coldwater, N. Y.
7. Iowa Expt. Station, Ames, Ia.
8. K. C. Livermore, Honeoye Falls, N. Y.
9. Mich. Agr'l Expt. Station, E. Lansing, Mich.
10. Purdue Agr'l Expt. Station, La Fayette, Ind.
11. O. H. Will Co., Bismark, N. D.
12. J. E. Sheeley, Monroe, Mich.
13. W. W. Barron, Mason, Mich.
14. Jerome B. Rice Co., Cambridge, N. Y.
15. Francis C. Stokes Co., Philadelphia, Pa.
16. Northrup King Co., Minneapolis, Minn.
17. Farmer Seed Co., Faribault, Minn.

To determine what characters, if any, are associated with susceptibility to wilt infection, certain coefficients of correlation were determined, these are presented in Table II.

It is evident, from Table II, that there is a marked negative correlation between number of days to maturity and per cent wilt at maturity. The difference between the correlation coefficients of the yellow varieties and all varieties, yellow and white commercial strains and resistant hybrids, is not significant. The means for per cent wilt and number of days for the yellow and all varieties would necessarily

TABLE II—CORRELATIONS OF CERTAIN CHARACTERS WITH PERCENTAGE OF WILT

Number and Type of Corns	Correlation Mean Days to Maturity and Final Per cent Wilt	Mean Per cent Wilt	Number of Days to Edible Maturity
59 Commercial yellow varieties....................	—.84±.026	57.16±2.22	74.72±.51
All Commercials (yellow and white) and hybrid corns....	—.83±.021	48.47±1.79	77.64±.51
Number and Type of Corns	**Correlation Between Per cent Wilt in Greenhouse and Final Reading**	**Correlation Between Germination Per cent and Final Wilt Reading**	**Correlation Between Yield and Final Per cent Wilt**
All Commercials (yellow and white) and hybrid corns....	.315±.088	—.468±.096	—.642±.059

differ, since most of the hybrid corns matured much later and had lower wilt infection.

The correlation coefficient between per cent wilt in the field and the percentage of seed-borne wilt because of its large probable error probably is not significant. This would indicate that the spread of wilt, by insects or otherwise, largely determines the final percentage of wilt infections, rather than amount borne in the seed. This is further substantiated by the fact that there was no correlation between seedling wilt and total marketable ears harvested.

Table I shows that some of the seed samples had a fairly low germination in the greenhouse. Many growers have stated that they encountered poor germination in 1933 from seed saved from their own crop. Poor germination obviously is caused by many factors, but the correlation coefficient between germination per cent and per cent wilt of seedlings in the greenhouse was –.468±.096. The probable error is quite large for this coefficient to be highly significant, but it is at least indicative.

That spread of the disease by insects or other means largely determines the final amount of wilt is further brought out by the non-significance of a correlation of –.323±.052 between per cent wilt on the first reading (June 12) at Monroe and the total marketable ears harvested. A correlation of –.642±.059 between per cent wilt on the final reading and total marketable ears is certainly significant and shows almost beyond question that in fields showing a high percentage of wilt the yield is materially reduced. This was more marked with the earlier than with the later varieties during 1933.

It is a recognized fact that heavy wilt infection reduces the total yield, but in order to substantiate this, the correlation coefficient was determined between total marketable ears and per cent wilt at the first reading and at the final reading. The coefficient was –.323±.052, which is too low and with too high a probable error to indicate a

significant relationship between the amount of wilt when the plants are eight inches high and subsequent yield. However, total ears and per cent wilt at the final reading showed a correlation coefficient of $-.642 \pm .059$ which is significant, and strongly indicates that though bacterial wilt may not kill the plant its presence seriously reduces the number of marketable ears.

The Use of the Regression Coefficient and Chi-square Methods for Testing the Significance of Deviations in Per Cent of Wilt

With a high correlation coefficient and linear correlation it is possible to predict values from the independent variable. The average number of days to edible maturity is taken as the independent variable (y) and per cent wilt at maturity as the dependent (x). The regression coefficient then is determined from the following formula by Fisher (2):

$$X = r \frac{\sigma x}{\sigma y} y$$

By substitution of number of days (y) in the above equation the per cent of wilt (x) can be determined.

Let us take seven of the 1933 F_1 selfed selections of Golden Bantam, compute the per cent wilt based on the line of regression, and see whether they differ significantly from the entire population.

TABLE III—Seven F_1 Selfed Golden Bantam Selections from the Michigan Station

Progeny Number	331234	331232	331231	331235	331225	331224	331233
Average No. days to (y) maturity..	76	77	77	78	78	78	81
Observed per cent wilt............	52.8	57.1	38.9	46.3	50.0	36.9	25.5
Cal. per cent wilt on y axis........	53.80	50.33	50.33	47.42	47.42	47.42	38.62
Deviation.........	— 1.00	+6.77	—11.43	—1.12	+2.58	—10.52	—13.12

It is apparent from Table III that the deviations of the calculated from the observed are not greater than those observed among all varieties. These inbreds, selected for resistance, are apparently no more resistant than other corns of comparable maturity date.

Many hybrid corns, according to some workers have shown a high degree of resistance to wilt. Apparently resistance in these cases has been determined by the crop actually produced. Hybrid corns are more vigorous than inbreds and most of them are late. Data for 13 hybrid corns from the Iowa Experiment Station and Golden Cross Bantam from the Purdue Station are presented in Table IV with the actual and calculated wilt percentages. Most of these hybrids were distinctly more vigorous than commercial hybrids offered by seedsmen.

A study of the deviations given in the last line of Table IV, shows that there are seven hybrids having striking minus deviations. These

have been marked with an "S". The other deviations are no larger than would be expected in a random sample from the entire population.

Seven of the 14 hybrids have Purdue Bantam (1339) as one parent, and five of these seven show significant deviations: Purdue Bantam from the Purdue Station, however, had 35 per cent wilt in 1933 and 90 per cent in the 1934 trials. The earliest corn is Purdue 1339 x Extra Early Bantam and this hybrid shows a non-significant deviation. All of the progenies showing significant deviations exhibited a marked degree of heterosis. All the inbreds used for crossing on Purdue 1339 and for the top crosses with the exception of Golden Cross Bantam, listed in Table IV are, according to Haber[2], F_7 inbreds from a cross of Evergreen sweet corn on Reid's yellow dent field corn.

TABLE IV—OBSERVED AND CALCULATED PERCENTAGES OF WILT OF 14 HYBRID CORNS

	45 X 1339	28 X 69	51 X G. Bant.	69 X 6	40 X 1339	28 X 45	40 X G. B
Observed No. days	74	81	79	80	76	79	73
Observed per cent wilt	37.50	38.60	32.70	26.70	30.00	36.70	60.00
Cal. per cent wilt on Y axis	59.06	38.69	44.51	41.60	53.24	44.51	61.97
Dev.	—21.56 S*	—0.09	—11.81	—14.90 S	—23.24 S	— 7.81	— 1.97
	2 X 1339	8 X 1339	8 X G. B.	28 X 1339	6 X 1339	E. E. B. X 1339	Golden Cross Bantam Purdue Expt. Sta.
Observed No. days	80	76	74	81	79	72	79
Observed per cent wilt	16.30	21.00	33.30	50.00	12.90	66.70	34.00
Cal. per cent wilt on Y axis	41.60	53.24	59.06	38.69	44.51	64.88	44.51
Dev.	—25.30 S	—32.24 S	—25.76 S	+11.31	—31.61 S	+ 1.82	—10.51

*S = significant.

In order to determine whether the two groups of corns given in Tables III and IV are subsamples taken from a homogeneous population, the chi-square test for homogeneity, given by Snedecor and Irwin (6), will be applied to these data. The test for homogeneity is given in Table V, and Fisher's test for significance, as suggested by Snedecor and Irwin (6) in Table VI.

The probability of .07 is quite low for the inbreds, but the value of .147 (Table V) for the hybrids would indicate that these two subsamples might tentatively be considered as having been taken from a population in which a uniform probability of infection is the general rule. The high correlation between maturity date and infection would

[2]Haber, E. S. Personal correspondence of October 23, 1934.

TABLE V—CHI-SQUARE TEST FOR HOMOGENEITY OF TWO GROUPS OF CORN

—F_1 Inbreds of Golden Bantam				Vigorous Hybrid Corns			
	n	s	p		n	s	p
Pedigree Number	No. Plants	No. Infected Plants	Per cent Infection	Pedigree Number	No. Plants	No. Infected Plants	Per cent Infection
331234	34	18	52.94117	45X1339	40	15	37.50000
331232	28	16	57.14285	69X6	45	12	26.66666
331231	54	21	38.88888	40X1339	50	15	30.00000
331235	41	19	46.34146	2X1339	43	7	16.27907
331225	32	16	50.00000	8X1339	36	12	33.33333
331224	46	17	36.95652	8XG. B	36	12	33.33333
331233	47	12	25.53191	6X1339	31	4	12.90322
	Σn 282	Σs 119	$\bar{p}=42.19858$		Σn 281	Σs 77	$\bar{p}=27.40213$

$\bar{p}=\frac{100\Sigma s}{\Sigma n}=42.19858$ per cent . . . . $\bar{p}=27.40213$ per cent

$\bar{q}=100-\bar{p}=57.80142$ per cent. . . . . $\bar{q}=72.59787$ per cent

$X^2=\frac{100\,(\Sigma sp-\bar{p}\Sigma s)}{\bar{p}\bar{q}}=11.3726$ $\qquad X^2=9.4555$

P = .072 $\qquad$ P = .147

TABLE VI—FISCHER'S TEST OF SIGNIFICANCE

	Number of Strains N	Degrees of freedom	Variance σ^2	Sum of Squares Nσ^2
F_1 inbreds.	7	6	98.3665	688.5655
Hybrids.	7	6	66.9403	468.5821
Totals.		12		1157.1476

Difference between (weighted) mean percentages = 14.7964 per cent

Pooled estimate of variance $=\frac{1157.1476}{12}=96.4289$

Variance of mean differences $=96.4289\,(1/7+1/7)=27.5511$

Standard Dev. of mean difference $=\sqrt{27.5511}=5.24$

$t=\frac{14.7964}{5.24}=2.824$ $\qquad$ P = below .02 and significant

be one factor that would lower the probability value in these two subsamples. If the samples had been so arranged that the strains of varieties had comparable maturity dates, no doubt the probability values would have been more significant. Furthermore, the values would indicate that, the technique of using infected plants as a measure of resistance, was adequate.

The test for significance (Table VI) between the weighted means of the two subsamples shows beyond doubt that the difference is significant. The seven hybrids exhibiting marked heterosis then were the only early or midseason strains or varieties which showed significantly lower wilt infection than other corns of the entire 1933 population of the same maturity date. There were other hybrids

which reached edible maturity 10 days to 2 weeks later that showed lower wilt infection than these hybrids.

The data for the 1934 trials are presented in Table VII. In this year wilt was materially affected by environmental conditions. May and June were abnormally hot and dry; seed germinated unevenly, and growth was slow. These conditions are unfavorable for the development of wilt, as has been shown by Rand and Cash (4). Wilt was not apparent until July 20, 2 weeks after a rainfall of 1.64 inches. By this time such varieties as Golden Gem, Spanish Gold, Golden Early Market and Extra Early Bantam were approaching maturity. These extremely early varieties did not have as high percentage of wilt infection as in the previous year and they produced a fairly satisfactory crop before wilt could cause any great damage. It is apparent from Table VII that there is a marked increase in wilt infection on corns later than these above, starting with the Sunshine variety. The first three hybrid corns tested were also fairly well matured before wilt was evident. The poor yield on the later corns was due primarily to very poor pollination caused by excessively high temperatures during tasseling. The hot dry conditions so hastened the maturity dates of the midseason and late varieties that the normal differences in maturity dates between these varieties were less than normal. After wilt started it spread rapidly and varieties such as Bardens Wonder Bantam, and Golden Cross Bantam showed a much higher per cent wilt than in 1933. One replication of Purdue Bantam was entirely killed by wilt when the ears had almost reached edible maturity. The yield in general was not affected by wilt as severely as in 1933 due to the lateness of infection.

TABLE VII—PER CENT WILT, DAYS TO EDIBLE MATURITY, AND YIELD OF CORNS GROWN IN 1934

Variety or Strain	Source*	Per cent Wilt (Mean)	Number of Days to Maturity (Mean)	Number Marketable Ears per Acre (Mean Thousands)
Commercial Corns				
Golden Gem	11	32.8	67.1	10.0
Golden Gem	8	48.9	68.8	9.0
Spanish Gold	4	35.8	68.2	12.6
Spanish Gold	6	24.2	71.3	8.2
G. Early Market	1	36.0	73.4	7.3
G. Early Market	6	46.7	71.7	8.9
E. Early Bantam	12	39.1	74.1	10.1
E. Early Bantam	6	37.4	73.9	10.1
Sunshine	14	67.9	78.5	3.7
Sunshine	11	65.5	75.7	7.1
Sunshine	6	75.5	75.4	4.2
Vanguard	15	31.3	80.6	5.8
Bardens W. Bantam	1	48.1	86.1	2.4
Hybrid Corns				
Kingscrost	16	22.7	76.4	7.6
E. Bant. Cross	16	37.2	77.8	5.0
Span. Gold X 7	4	29.6	75.2	10.8
G. E. M. X 7	4	62.4	77.8	6.4
Whipple Cross (2x12) X 39	4	43.3	86.6	4.5
Whipple Cross 7 X 6	4	62.7	80.2	4.4

TABLE VII—*Continued*

Variety or Strain	Source*	Per cent Wilt (Mean)	Number of Days to Maturity (Mean)	Number Marketable Ears per Acre (Mean Thousands)
Hybrid Corn				
Whipple X 39	4	43.6	86.0	5.2
Minnhybrid 201	17	53.8	88.8	1.7
Minnhybrid 202	17	60.2	85.7	4.4
Minnhybrid 203	17	67.3	83.1	4.2
51 X G. Bantam	7	37.9	90.6	8.1
8 X 1339	7	17.2	91.0	7.4
8 X Chap. G. Bantam	7	11.8	84.3	3.7
2 X 1339	7	15.0	92.9	10.0
Gold. Cross Bantam	10	49.5	91.1	7.7
Top Cross Bantam	1	38.8	92.4	6.0
Top Cross Bantam	8	52.1	88.8	6.1
Bantam Everg. Hyb	1	48.1	86.1	3.2
Inbreds				
341580—G B. F_2	9	53.7	80 to 85	—
341581—G. B. F_2	9	37.6	80 to 85	—
341583—G B. F_2	9	51.1	80 to 85	—
341585—G B. F_2	9	93.8	76	—
341586—G B. F_2	9	81.0	76	—
341587—G B. F_2	9	22.7	74	—
Purdue 1339 F_7	9	90.0	86	—
341589—Whipple F_4	9	66.7	82	—
341590—Whipple F_4	9	31.1	86	—
341595 E. E. B. F_2	9	60.4	74	Innoculated in 1933
341596 E. E. B. F_2	9	48.8	76	Innoculated in 1933
341596—E. E. B. F_2	9	39.6	76	—
341504—1 G. B. F_1	9	30.4	83.4	4.6
341504—2 G. B. F_1	9	33.3	83.1	3.6
341504—3 G. B. F_1	9	25.0	83.5	4.2
341504—4 G. B. F_1	9	23.1	84.5	5.3
341504—5 G. B. F_1	9	20.0	82.7	3.9
341504—6 G. B. F_1	9	46.1	84.3	5.8
341504—7 G. B. F_1	9	55.5	82.6	4.4
341504—8 G. B. F_1	9	52.6	84.4	3.4
341504—9 G. B. F_1	9	48.1	81.2	2.4
341504—10 G. B. F_1	9	25.0	82.7	3.5
341504—11 G. B. F_1	9	50.0	83.3	3.8

*1. Associated Seed Growers, New Haven, Conn.
2. W. Atlee Purpee, Philadelphia, Pa.
3. Burnham and Morrill, Portland, Me.
4. Conn. Agr'l Expt. Station, New Haven, Conn.
5. Ferry-Morse Seed Co., Detroit, Mich.
6. Harris Seed Co., Coldwater, N. Y.
7. Iowa Expt. Station, Ames, Ia.
8. K. C. Livermore, Honeoye Falls, N. Y.
9. Mich. Agr'l Expt. Station, E. Lansing, Mich.
10. Purdue Agr'l Expt. Station, La Fayette, Ind.
11. O. H. Will Co., Bismark, N. D.
12. J. E. Sheeley, Monroe, Mich.
13. W. W. Barron, Mason, Mich.
14. Jerome B. Rice Co., Cambridge, N. Y.
15. Francis C. Stokes Co., Philadelphia, Pa.
16. Northrup King Co., Minneapolis, Minn.
17. Farmer Seed Co., Faribault, Minn.

Since the linear negative correlation between maturity and wilt was so pronounced in the 1933 trials, and since certain hybrids exhibited marked minus differences in wilt percentage, the 1934 types have been grouped into five classes (Table VIII). The extremely early commercial corns were not included, as wilt had very little effect on them. All of the hybrids have been included.

TABLE VIII—STATISTICS ON PERCENTAGE OF BACTERIAL WILT IN FIVE GROUPS OF CORN

	Golden Bantam F_1 Selfs, 81.2 to 84.3 Days	Golden Bantam F_2 Selfs, 80 to 85 Days	Hybrid Corns, 75.2 to 85.7 Days	Hybrid Corns, 86.0 to 98 Days	Commercial Corns, 75.0 to 86 Days	Total
No. of progenies (av. of 3 replicates)....	11	7	8	10	5	41
Sum of percentages..	409.1	410.7	353.9	369.2	288.3	1831.2
Mean percentages...	37.19	58.67	44.24	36.92	57.66	46.94

To indicate the significance of the differences in mean per cent of wilt between the various groups of corn, Fisher's (2) analysis of variance method is presented in Table IX.

TABLE IX—ANALYSIS OF VARIANCE OF PERCENTAGE OF WILT IN FIVE GROUPS OF CORN

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total..............................	40	15,419.63	385.49
Between means of groups.............	4	3,433.38	858.34
Within groups.......................	36	11,986.25	332.95

Standard Deviation = 18.25 per cent,
Standard Error of the mean = 2.84 per cent

The extremely large mean square for "between means of groups" indicates that the variation between means might be significant. However, "F" calculated according to Snedecor (5) gives a value of 2.58 which from his Table 35 for values of "F" and "t" is not significant.

To test the difference between two groups of corn having comparable maturity dates, the standard deviation can be used to calculate the standard error of the difference. From these statistics "t" can be obtained (Snedecor, 5). These statistics are presented in Table X.

TABLE X—A TEST FOR SIGNIFICANCE BETWEEN MEANS OF INDIVIDUAL GROUPS

	Difference (Per cent)	Standard Error of Difference (Per cent)	"t" Significance
Golden Bantam F_1 selfs Golden Bantam F_2 selfs	21.48	8.76	2.45 Significant
Early hybrids, 75–86 days Commercials, 75–86 days	13.42	10.4	1.29 Not significant
Late hybrids, 86–98 days Commercials, 75–86 days	20.74	10.04	2.07 Barely significant

The largest value of "t" and the difference showing the greatest significance was between the two groups of inbreds. The F_2 selfs were

much less vigorous than the F_1 selfs. This further substantiates the view that growth rate, or vigor, as shown by the very vigorous Iowa hybrids in 1933, may be one of the causal factors for lower wilt percentages. The early hybrids, with one exception, were not noticeably more vigorous than the commercials of comparable maturity dates. As shown in Table X, the difference between early hybrids and commercials was certainly not significant. A top cross of Spanish Gold x 7 from the Connecticut Station was slightly more vigorous than the other early hybrids and showed 29.6 per cent wilt as compared to the mean of 44.2 per cent for the entire group.

One would certainly expect the difference between the means for 75–86-day commercials and 86–98-day hybrids to be significant. However, the value of "t" is but 2.07, only slightly higher than the minimum value of significance 2.03 (Snedecor's Table 35).

One F_2 inbred progeny of Golden Bantam (341587) averaged only 22.7 per cent wilt as compared to 58.67 per cent for the entire group. The F_1 of this progeny (331233) exhibited 25.5 per cent wilt and this was the only inbred in 1933 that showed any indication of a minus difference (Table III).

To determine the presence or absence of correlation within groups, between days to maturity and per cent wilt, the varieties and strains are reclassed in Table XI. The early commercials not presented in Table VIII are included, but the F_2 Golden Bantam inbreds are not included since these progenies were used for making further selfs and crosses and complete harvest records were not taken. The analysis of variance and covariance are given in Tables XI and XII.

All of the hybrid corns, both early and late, have been included in a single class in Table XI, and since the very early commercial corns are included in a separate class, one would expect the variance between means of the groups to be larger than that exhibited in the classification in Table IX. This is not the case, since "F" is only 2.32 as compared to 2.58 for the earlier classification. It would appear that grouping all hybrids together tends to smooth out the curve of variance to such an extent that the early corns comparatively low in wilt percentage failed to cause a significant difference between means of the groups.

Due to adverse environmental conditions during 1934 and the late infection of wilt, the correlation between maturity date and wilt was not as evident in the field as it was in 1933. From Table XII, it is evident that there is no significant correlation either for the population as a whole or within specific groups. The absence of correlation during this season was to be expected. The late corns showed much more wilt than in 1933 due to late infection, and the early corns less. Furthermore, the normal spread between maturity dates for the various varieties and strains was materially decreased due to high temperatures and drought.

Irrespective of the low yields due to poor pollination there was a significant negative correlation between per cent wilt and total marketable ears per plot in 1934. The coefficient was $-.46 \pm .015$. According to Fisher's table of values of "r" for different levels of significance, "P" is below .01 which is significant

TABLE XI—DAYS TO MATURITY TOGETHER WITH PERCENTAGE OF WILT OF THREE REPLICATIONS OF 30 PLANTS EACH OF SWEET CORN, 1934

Type	No. of Varieties	Days or Wilt	Days to Average Maturity After Planting, and Per cent Wilt									Sum	Sum of Squares	Sum of Products	Mean
Early commercials Spanish Gold up to Sunshine	8	days	67.2	68.8	68.2	71.3	73.4	71.7	74.1	73.9	—	568.6	40,464.68	—	71.07
		wilt	32.8	48.9	35.8	24.2	36.0	46.7	39.1	37.4	—	300.9	11,738.79	21,387.46	37.61
Commercials Sunshine and later	5	days	78.5	75.7	75.4	86.1	80.6	—	—	—	—	396.3	31,487.47	—	79.26
		wilt	67.9	65.5	75.5	48.1	31.3	—	—	—	—	288.3	17,894.21	22,645.39	57.66
All hybrid corns	18	days	76.4	77.8	88.8	85.7	83.1	91.0	90.6	84.3	92.9	—	—	—	—
		wilt	22.7	37.2	53.8	60.2	67.3	17.2	37.9	11.8	15.0	—	—	—	—
		days	92.4	88.8	91.1	97.9	75.2	77.8	86.6	80.2	86.0	1547.1	133,593.90	—	85.95
		wilt	38.8	52.1	49.5	18.0	29.6	62.4	43.3	62.7	43.6	722.2	34,514.55	61,636.64	40.12
F_1 Golden Bantam Inbreds	11	days	84.5	82.7	84.3	82.6	84.4	81.2	81.0	83.0	82.0	—	—	—	—
		wilt	23.1	20.0	46.1	55.5	52.6	48.1	30.4	33.3	25.0	—	—	—	—
		days	82.0	84.7	—	—	—	—	—	—	—	912.4	75,697.68	—	82.94
		wilt	25.0	50.0	—	—	—	—	—	—	—	409.1	17,002.49	33,982.94	37.19
Totals	42	—	—	—	—	—	—	—	—	—	—	3424.4	281,243.73	—	—
			—	—	—	—	—	—	—	—	—	1720.5	81,150.04	139,652.43	—

TABLE XII—ANALYSIS OF VARIANCE AND COVARIANCE; DAYS TO MATURITY AND PER CENT WILT OF FOUR GROUPS OF CORNS

Source of Variation	Degrees of Freedom	Average No. Days to Maturity		Per cent Wilt		Covariance		
		Sum of Squares	Mean Square	Sum of Squares	Mean Square	Sum of Products	Correlation Coefficient	Regression of Wilt on Days
Total	41	2,040.98	49.78	10,670.99	260.27	—625.67	—.13	—
Between means of groups	3	1,273.90	424.63	1,652.98	550.99	— 34.92	—.024	—.027 %per day
Within groups	38	767.08	20.19	9,018.01	237.32	—590.75	—.23	—.77% per day.

Standard Dev. =15.4 per cent   Standard Error of mean =2.39 per cent   Between means of groups F =2.32

Conclusions and Discussion

1. When the percentage of infected plants in the field is taken as the criterion of wilt resistance, it has been found that Top-cross Bantam, Bantam Evergreen hybrids, Golden Cross Bantam, and Kingcrost are no more resistant than open-pollinated varieties of comparable maturity date.
2. The presence or absence of correlation of certain characters with wilt percentage are as follows:
   a. A high negative correlation between final per cent wilt and days to edible maturity in 1933.
   b. A negative correlation between final per cent wilt and yield of marketable ears in 1933 and 1934.
   c. No correlation between seedling infection and final wilt reading in the field in 1933.
   d. No correlation between seedling wilt and yield of marketable ears in 1933.
3. When the regression coefficient, based upon the high linear correlation of 1933, was used to predict the per cent of wilt, using days to maturity as the independent variable, it was found that:
   a. The deviations of the predicted from the actual per cent wilt for seven F_1 inbred Bantams, selected for resistance, were not significant.
   b. When 14 hybrid corns grown in 1933 were tested seven showed minus deviations which were apparently significant. Golden Cross Bantam did not show a significant deviation.
   c. When tested for homogeneity by the chi-square method (Tables V and VI) both subsamples appeared to be taken from a homogeneous population.
4. One parent of the seven hybrids showing low wilt infection, was an F_7 inbred from a cross of Reid's yellow dent field corn on Evergreen sweet corn.
5. The early maturing strains, up to 75 days grown in 1934 had markedly less wilt than later ones and much less than in 1933. Wilt was not evident in 1934 until these earliest varieties were approaching edible maturity.
6. Excluding the earliest varieties, all of the other corns grown in 1934 were grouped into five classes (Table VIII) in order to apply Fisher's analysis of variance. From this analysis it was found that:
   a. The differences between means of the five groups of corn were not significant.
   b. The difference in mean per cent wilt, between hybrid corns and commercial varieties of comparable maturity dates, was not significant.
   c. The difference between mean wilt percentage of the F_1 and F_2 Golden Bantam inbreds gave a "t" (Table X) of 2.45 which is significant.
   d. The difference between mean wilt percentage for the 75 to 85 day commercials and the 86 to 98 day hybrids was barely significant.

7. When the above-mentioned groups were also subjected to a test of analysis of "variance and covariance" (Table XII), it was found that:
   a. The total correlation, correlation between means of groups, and correlation within groups, of per cent wilt and days to maturity, was not significant.

From the data obtained during the markedly different seasons of 1933 and 1934, the question is raised as to what constitutes resistance, of corn to bacterial wilt under field conditions. Is there true resistance, or is the ability to produce a crop due to tolerance of wilt or ability to escape disease?

The fact that during 1934 very susceptible corns failed to show infection until after July 15, points strongly to environmental conditions as largely influencing the development of wilt, on the earliest maturing varieties. This may be regarded as disease escape. In 1933 these corns were heavily infected and practically wiped out, whereas, the same strains in 1934, though showing wilt infection, still matured a crop.

Certain mid-season and late strains during both seasons showed a high percentage of infection in leaves and stalks, but matured a crop. This would indicate that due to some inherent characters the plants are able to survive infection and produce at least a partial crop, i. e., they are disease tolerant.

Field observations and statistical analyses have demonstrated that the only strains which had significantly lower infections, were hybrids having marked vigor, or heterosis. All these hybrids had as one parent an inbred obtained from a cross of Evergreen Sweet Corn on Reid's yellow dent field corn. This parentage probably accounts for the marked vigor of these hybrids. It would appear then that hybrid vigor might be a possible explanation for the resistance of these hybrids. Martin (3) has found a high correlation between size of stem and number of vascular bundles, between size of stem and size of vascular bundles, and between size of stem and number of surface roots. Is this the explanation then of why these large-stemmed, vigorous, hybrid plants show less infection and are able to grow and produce a normal crop? If so, resistance would appear to be associated with anatomical rather than genetic factors, yet Wellhausen (7) in a preliminary paper, states that he has found one inbred of field corn and one inbred of Black Mexican that have shown Mendelian segregation for wilt resistance in the F_2 and F_3 generations. His conclusions are based upon survivals from hypodermic inoculations of seedlings both in the greenhouse and in the field. If a resistant inbred of field corn can be obtained, it should be possible by convergent improvement to develop a resistant hybrid sweet corn, using the resistant field corn inbred as the recurrent male parent. However, would the development of higher quality, vigorous early sweet corn hybrids be the most logical plant breeding method?

The majority of single, double, and top-crossed corns tested, however, did not exhibit any more resistance than open-pollinated commercial varieties of comparable maturity date unless heterosis was strongly manifested. Varieties such as Golden Cross Bantam, Top-

Crossed Bantam, Bantam Evergreen top crosses, and Kingcrost were not resistant when infected plants were used as a basis for determining resistance. It is true that many of these hybrids consistently outyield open-pollinated varieties of comparable maturity date, but can this difference be attributed to the effect of wilt on the open-pollinated varieties, or would not this difference be maintained if both were grown under wilt-free conditions?

It is fully admitted that the conclusions and interpretations presented are based on only 2 years of effort, and the spread, as to number of varieties, crosses, etc., was exceedingly wide and somewhat thin. The results, however, are indicative and it is hoped that they may be suggestive.

It is quite apparent that hybrid varieties for many reasons will be more popular in the future than they have been in the past. However, single-, double-, or top-crossed corns will not necessarily be tolerant of wilt merely by virtue of the fact that they are hybrids. It has been suggested that heterosis is to be desired in hybrids, but frequently plant breeders are limited to line-bred inbreds of a particular variety, and, since these are more or less related, the expected vigor is not obtained when several of these inbred lines are crossed. In order to secure hybrid vigor, it is often necessary to cross inbreds from varieties with marked contrast for several characters. However, if a definite type is desired, such as an 8-rowed ear, it may be necessary for plant breeders to exchange 8-rowed inbreds in order to obtain lines selected from different stocks. Exchange of inbreds by workers from different regions and the testing of these lines with local inbreds, to develop a strain adapted to that locality, might materially hasten the development of early, vigorous, locally adapted wilt tolerant hybrids.

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Breeding Cucumbers Resistant to Scab

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IN recent years many inquiries have been received by the Maine Agricultural Experiment Station relative to a disease of cucumbers commonly called scab, caused by *Cladosporium cucumerinum*. Serious loss is experienced by many growers, particularly in cool, humid summers and during the latter part of the growing season. Frequently the entire crop is a failure. Spraying or dusting has been found to give partial control but the many difficulties concerned, even with such treatment, have shown the need for solution of the problem by breeding a resistant variety of desirable market type.

Accordingly, in the summer of 1931, work was begun on an inbreeding program with plans for subsequent testing for resistance and selection within inbred lines. Selected plants of 22 varieties of cucumbers were self-pollinated. From 4 to 12 successful self-pollinations were obtained of each variety. This produced a total of 125 seed lots including all varieties. The complete list of varieties employed is as follows: Arlington White Spine, Boston Pickling, Chicago Pickling, Davis Perfect, Early Fortune, Early Russian, Fordhook Famous, Golden Harvest, Green Pack, Harris Double Yield, Harris Perfection, Heinz Special, Henderson, Jumbo, Kirby, Klondike, Longcu, Longfellow, National Pickling, Snow's Perfected Pickle, Windemoor Wonder, and Woodruff Hybrid.

During the winter of 1931–32, the 125 inbred seed lots were tested for scab resistance under the direction of Dr. Folsom of the Department of Plant Pathology. This was done by artificial inoculation using a spore suspension of the scab organism obtained from the disease cultured on potato agar. Approximately 50 seedlings grown from each seed lot were used as a sample of the population. Omitting discussion of the many difficulties and details involved, the net result of the test was as follows: Of the 125 seed lots tested, 117 exhibited no resistance in the seedling stage. Practically every seedling of these populations developed the disease which in most cases was lethal. The remaining eight lots gave indication of resistance of different degrees; two of these exhibited complete freedom from infection. Unfortunately, all the resistant populations were from late maturing, long-fruited, slicing varieties. The pickling and early slicing types are in greater demand in Maine, but the selfed populations from them were all found to be practically 100 per cent susceptible to scab.

To demonstrate the infrequency of resistant seedlings, even in the varieties from which such material was derived, the following instance may be mentioned. In the effort to increase the quantity of resistant breeding stock, about 1,000 seedlings of the Longfellow variety were artificially inoculated with scab to test them for resistance. In none of the seedlings was definite resistance apparent.

During the summer of 1932, samples of about 90 of the seed lots tested in the greenhouse were planted in the field chiefly for the purpose of determining the significance of the greenhouse seedling test in relation to field behavior at fruiting time. Each of the 22 varieties previously mentioned was represented by one or more of the selfed

selections. Ten hills of each lot were planted to be used as an index of the behavior of the population. A scab susceptible commercial variety, Boston Pickling, constituted every fifth row in the plot and served as a check. The presence of scab in the field was obtained uniformly in severe degree by artificially inoculating two hills of each check row and all hills of the seed lots tested. In addition, diseased fruits were scattered about the field to provide a continuous source of inoculum. A close correlation between susceptibility in the seedling stage and behavior in the field was evidenced by information obtained during the summer.

The following conditions were found to exist:

1. All inbred seed lots which produced seedlings highly susceptible to scab in the greenhouse tests, produced plants susceptible in the field. Practically every plant of these lots produced scabby fruits in the field or developed lesions on the stem.

2. The lots which were resistant in the seedling stage in the greenhouse showed a similar degree of resistance in the field. All such seed lots gave at least some plants showing no evidence of disease.

3. All plants producing scabby fruits exhibited scab lesions on the stems and leaves. The reciprocal statement, however, is not true as some plants with scabby stems and leaves produced clean fruits. This fact may possibly be attributed to the rapidity of fruit growth during periods unfavorable to scab development. For this reason the presence or absence of the disease on the stems and leaves is probably a better criterion for estimating susceptibility under field conditions than examination of the fruits.

A study of the genetic nature of the inheritance of resistance to scab is in progress and a small quantity of information has been obtained. By further work with the eight initial seed lots that exhibited varying degrees of resistance it was found that two of these eight lots continued to breed true for resistance upon continued selfing. They were the ones entirely free from infection in the first population test. It would seem that homozygous resistant plants had been selfed to produce these two lines. The remaining six lots which showed partial resistance in the first test have continued to produce progeny segregating for resistance thus indicating heterozygosity for the character. Resistant individuals of 127.31, one of the Longfellow seed lots exhibiting partial resistance, were crossed with selections from some of the self-pollinated seed lots which showed nearly 100 per cent susceptibility when tested. The former were considered to be either heterozygous or homozygous for resistance while the latter were homozygous for susceptibility. The F_1 seedling populations were artificially inoculated with a spore suspension from the scab fungus. The data obtained from this test are given below.

Cross	Number Healthy	Number Diseased	Probable Ratio	D/PE
127.31–1 x Davis Perfect........	25	23	1:1	.4
127.31–2 x 4–5................	55	48	1:1	1.0
127.31–3 x 6–1................	15	13	1:1	.6
47–3 x 127.31–4................	6	6	1:1	.0
127.31–5 x 56–7..............	52	0	—	—
149.31–1 x Davis Perfect.......	93	25	3:1	1.2

A hypothesis to explain the above results can readily be set forth when it is remembered that lines 127.31 and 149.31 were heterozygous for resistance as evidenced by further selfing, and further, that one parent in every cross was considered to be homozygous for susceptibility as evidenced from progeny seedling tests. In the first four crosses listed, it would appear that the resistant parent was heterozygous for a single factor causing resistance. In the fifth cross, it would appear that a homozygous resistant parent had been selected from a segregating population, 127.31 and that complete dominance occurs. In the last cross, a different situation appears to exist. Seed lot 149.31 from Windemoor Wonder produced both resistant and susceptible plants upon further selfing but the progeny was too small to furnish a clue as to the probable number of factors involved. However, its heterozygosity was evident. If we consider the Davis Perfect selection as the recessive susceptible, then a 3:1 ratio could be obtained in F_1 by means of heterozygous duplicate factors in the 149.31 selection, either one of which present in dominant form would produce resistance. There is the possibility, however, that the Davis Perfect plant used was also resistant and heterozygous in nature although as yet no resistance has been found in this variety or any of its progeny. If such were the case, only a single factor difference in each of the two parents of this cross would be necessary to explain the 3:1 ratio.

It should be noted that the deviation from the theoretical ratio in no case was significant. Also, the deviation in every case was due to an excess number of plants classed as healthy. This could well be possible as resistant plants could not be given the disease, but an occasional susceptible plant might escape infection in the test. Although the data thus far concerning the inheritance of resistance are very limited, it would seem that a small number of genetic factors are involved and the possibility exists that it may be explained by a single factor difference.

Seed Transmission of Mosaic in Inbred Lines of Muskmelons (*Cucumis Melo* L.)[1]

By C. H. MAHONEY, *Michigan State College, E. Lansing, Mich.*

IN the spring of 1932 and 1933 several cases of mosaic occurred among seedlings grown from various muskmelon inbreds and crosses. Typical mosaic was evident on the first true leaf of the young seedling and such evidence strongly indicated seed transmission. Doolittle and others, however, stated that the cultivated species of cucurbits rarely, if ever, transmit mosaic through the seed. Doolittle and Walker (2) found one case among 22,000 cucumber seedlings but obtained negative results from muskmelon seed harvested from mosaic plants. Doolittle and Gilbert (1) have shown, however, that the seed of wild cucumber, *Micrampelis lobata,* is capable of transmitting mosaic. In the face of this evidence it was assumed that insects must have been responsible for the infection.

Seedlings of 48 inbred progenies, of approximately 50 plants of each progeny, were grown in the spring of 1934. The seedlings were grown in wood veneer bands, set in a sash-covered frame which had not been previously used for growing melon or cucumber plants. The seedlings of six progenies exhibited a high percentage of mosaic infection with sib lines showing no infection. If 10 to 12 days are necessary for mosaic symptoms to be evident after infection by artificial means (4), these cases must have been seed-borne as mosaic was evident on the seedling leaves within a week after germination. It was not until midsummer of this same season that Kendrick (4) gave positive evidence of seed transmission of mosaic in the muskmelon.

No attempt was made to eliminate the infected seedlings before transplanting to the field. To do so would have reduced the number of plants in several progenies to the point where they would have been of no value in the melon breeding project. The lines which showed mosaic infection in the spring of 1934 with their sibs are presented in Table I.

The infected plants made rather slow growth in the field and the crown set of fruit was 10 to 14 days later than on healthy plants in the same row. The total early set of melons was only one-third to one-half that of the clean plants. Mosaic spread through the field rapidly and by September 15, with the exception of a few plants, the entire area was infected with mosaic. In addition to the inbreds, 16 commercial varieties were grown in the field. In August, fruits were tagged on plants which were apparently healthy at that time and also on infected plants. These tagged fruits were selected within the progenies which showed early infection in the cold frame. Seed was saved from these fruits and was planted in the greenhouse early in the fall. The data for the greenhouse test are presented in Table II.

It is clearly evident from Table II, that all plants which had mosaic when the fruit was harvested, transmitted the disease through the seed to its progeny. This was true for the four lines tested. Line

[1]Journal Article No. 209 (n. s.) from the Michigan Agricultural Experiment Station.

TABLE I—PERCENTAGE OF MOSAIC IN SEEDLINGS OF VARIOUS INBRED LINES GROWN, SPRING OF 1934

Variety or Type	Selfed Generation	1933 Progeny Number	1934 Progeny Number	Per cent Mosaic Infected Plants
Honey Rock	F_4	1276	1476	30.1
Honey Dew x Em. Gem	F_4	1285	1487	21.1
Honey Dew x Em. Gem	F_4	1285	1488	25.0
Honey Dew x Em. Gem	F_4	1285	1489	0
Su. Sweet x Honey Dew	F_4	1296	1490	33.3
Honey Dew Hybrid	F_2	1302	1501	0
Honey Dew Hybrid	F_2	1302	1502	0
Honey Dew Hybrid	F_2	1302	1503	0
Honey Dew Hybrid	F_2	1302	1504	14.3
Honey Dew Hybrid	F_2	1302	1505	0
Honey Dew Hybrid	F_2	1302	1506	0
Honey Dew Hybrid	F_2	1302	1507	0
Salmon Tint Pollock	F_2	1316	1514	20.0
Salmon Tint Pollock	F_2	1316	1515	0

1490 would appear to be more susceptible to mosaic infection than the other three with an average of 27.1 per cent infected plants in the greenhouse. This line also showed the highest percentage of seed transmission in the spring planting. The five selections from 1487 on the other hand had an average of only 8.9 per cent. Whether this difference between the two lines is significant cannot be determined as yet.

The three selections which showed no evidence of mosaic at harvest did not transmit mosaic to their progenies. Non-infected selections from inbred Honey Rocks and open-pollinated Honey Net produced large progenies free from mosaic.

DISCUSSION AND CONCLUSIONS

Kendrick (4) found that cucurbit mosaic was transmitted in the seed of 3 out of 23 packages of muskmelon seed. The seed used was from commercial open-pollinated varieties, and the percentages were 2.13, 0.15, and 0.094. Six out of 48 inbred progenies grown at the Michigan Experiment Station showed seed-borne mosaic. The average infection of these six progenies was 24 per cent. Further selections were made from these progenies in the field and in every case where the plant was infected it transmitted mosaic through the seed to its progeny. The average percentage of transmissions from all the infected plants was 15.6 per cent. Seed from non-infected plants from these same progenies failed to transmit mosaic through the seed. These percentages are extremely high when compared to Kendrick's figures. Can the differences be attributed to the fact that certain inbred lines are highly susceptible to mosaic infection and seed transmission? Clayton (3) stated that he thought resistant lines of cucumbers could be developed by inbreeding and selection. So far no evidence has been obtained to show that this is possible for the muskmelon, but the evidence presented indicates that some lines may be much more susceptible to infection than others. It would also indicate

TABLE II—GREENHOUSE TEST OF SELECTIONS TAKEN FROM PROGENIES SHOWING SEEDLING MOSAIC IN SPRING OF 1934

1933 Number	1286										1296					
Per cent seed borne mosaic spring 1934	21.1					25.0		0			33.3					
1934 field selection	1487–3	1487–7	1487–14	1487–18	1487–16	1488–1	1488–10	1489–10	1489–2	1489–12	1490–1	1490–3	1490–6	1490–11	1490–17
Condition of plant at fruit harvest	mosaic	mosaic	mosaic	late, slight	late, slight	free	mosaic	?	free	free	mosaic	mosaic	?	mosaic	mosaic
Per cent mosaic in greenhouse fall of 1934	17.0	2.8	6.9	1.0	16.7	0	12.6	14.3	0	0	27.3	26.6	18.5	27.9	35.4
Average per cent mosaic from infected plants	8.9					12.6		14.3			27.1				

that the melon breeder has something else to contend with, and it may be necessary to discard infected seedlings and transplant only healthy plants.

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Observations on Some Inbred Lines of Bush Types of *Cucurbita pepo*

By G. W. Scott, *University of California, Davis, Calif.*

Abstract

This paper will be published in full elsewhere.

FROM observations of second and third generation inbred lines derived from commercial seed of three bush varieties of *Cucurbita pepo,* the following conclusions seem justified:

1. Commercial stocks of the varieties White Bush Scallop, Yellow Summer Crookneck, and Succhine or Italian Marrow are heterozygous.

2. By inbreeding for only two or three generations, certain lines may be isolated, differing in habit of plant growth, size of plant, shape and size of fruit, character of external markings on the fruit, color of fruit, and type of leaf.

3. Further inbreeding is necessary to make other lines homozygous for any, or all, of these characters.

4. Vigor, as represented by plant size, fruit size, and yield of fruit, may be noticeably reduced in the second generation in some lines or may be equal to, or greater than, the original material after two or three generations of inbreeding in other lines. Rigid selection to eliminate lines of low vigor is necessary.

5. Self sterility in the inbred lines has not been a factor to contend with in this material.

6. The variations brought forth by inbreeding and the ease by which they may be isolated in the homozygous state would indicate that inbreeding of commercial stocks, accompanied by rigid selection, is a practical means of improvement of these commercial varieties.

Progress in Developing Muskmelon Strains Resistant to Fusarium[1]

By T. M. Currence and J. G. Leach, *University of Minnesota, St. Paul, Minn.*

IN 1932 a severe infection of Fusarium wilt was found in the muskmelon plantings of several market gardeners near Minneapolis, Minnesota. The plantings found infected were all located within a radius of about 1 mile. During the past season it was found that the infection had spread so that a radius of probably 2 miles was covered. The disease has also been found on one farm in one other locality. The disease is very destructive often destroying more than 95 per cent of the plants in a field. Since muskmelons constitute one of the most profitable crops for certain Minnesota market gardeners an attempt is being made to develop strains otherwise suitable which will be resistant to the disease. Although the work has been under way only three seasons it is thought that some progress has been made.

The program began by selfing as many normal plants as possible of Benders Surprise grown in a 6-acre field containing diseased soil. Twenty-eight of these plants developed to the stage of producing seeds. The following season (1933) the progenies were grown in comparison with a number of commercial varieties on diseased soil. Table I gives an indication of the relative resistance of the varieties and strains. It will be noted that the Honeydew, Casaba, Persian, and Honey Ball all show considerable resistance. Four varieties which were typical in reaction for a large group of more extensively grown muskmelons are also shown. Many others were tested but all were found to be from 80 to 100 per cent susceptible. Selection 73-33 appeared intermediate between the susceptible and resistant types. All others of the 28 selections were highly susceptible and are omitted from the table. Several healthy plants of 73-33 were selfed and the seed saved, as well as seed from a number of open pollinations of promising type. Progeny of the original 73-33 plant indicated that it was a cross between Benders Surprise and Honeydew since both of these types and various combinations of their fruit characters appeared in 1933.

In the season of 1934 extensive plantings were made of these seeds but unfavorable weather delayed growth of the plants to such an extent that selections could not be made for characters other than disease resistance. However, it was possible to obtain seeds from 150 selfed pollinations of resistant plants and a few open pollinations. As near as could be determined there were a number with fruit resembling that of Benders Surprise. However, none of these strains were entirely uniform for fruit type. Those lines which were most uniform are generally like Honeydew in appearance and certain ones gave indications of being sufficiently early to be of value for Minnesota conditions. Many of these plants appeared to be highly resistant

[1]Paper No. 1330 of the Journal Series of the University of Minnesota Agricultural Experiment Station. Cooperative investigation by the Division of Horticulture and the Division of Plant Pathology and Botany.

TABLE I—PERCENTAGE OF PLANTS SHOWING DISTINCT SYMPTOMS OF FUSARIUM WILT

Variety or Strain	Percentage of Plants Infected			
	6/12	6/27	7/17	8/24
Kleckley Sweet	0	0	0	0
Persian	17	29	33	43
Honey Ball	2	12	16	30
Honey Dew	17	22	33	35
Casaba	16	28	32	34
Emerald Gem	16	45	49	80
Benders Surprise	70	87	89	96
Sugar Rock	40	49	62	89
Pollock	46	64	70	93
Selection 73–33	31	43	52	56

to the disease. It is hoped that in 1935 complete records can be made of all strains relative to resistance, earliness, quality, productiveness, etc.

The authors are unable at present to explain the origin of the disease. The similarity of the pathogen to *Fusarium niveum* suggests that it may have arisen as a mutation of the watermelon Fusarium but there is no watermelon wilt in the districts where this disease has been found, and as shown by the table watermelons are not affected by the muskmelon pathogen. On the other hand this muskmelon wilt apparently has never been reported elsewhere.[2] If the disease does not exist elsewhere, of course, it eliminates the possibility that the organism was brought in by seed or some other method. It is hoped that future developments may offer a satisfactory solution to this question.

Horticulturists should be cautioned against this wilt because of its destructive nature and the ease with which it can be spread. When a plant dies from wilt after the fruit is almost mature the fungus will invade the fruit and infect the seed. Plants grown from such seeds, planted in sterilized soil, developed a high percentage of wilt. It therefore seems especially desirable to avoid introducing the fungus into seed growing areas from where it would readily be spread and would become widely disseminated.[2]

[2]Since submitting this paper for publication evidence has been obtained that the same disease, or a very similar one, occurs in the vicinity of Rochester, N. Y.

Bolting Habit of Different Varieties and Inbred Lines of Onions

By H. A. JONES and S. L. EMSWELLER, *University of California, Davis, Calif.*

ABSTRACT

This paper will be published elsewhere.

Breeding Snap Beans for Mosaic Resistance
A Progress Report[1]

By C. H. MAHONEY, *Michigan State College, E. Lansing, Mich.*

ONE of the plant breeding projects at the Michigan Station is an attempt to obtain late varieties or strains of snap beans which are either resistant to mosaic under field conditions or mosaic-tolerant. A large number of selections from commercial varieties and from several crosses have been carefully tested during the past four years under field conditions where adequate facilities for infection and spread of common bean mosaic (virus No. 1), were present. Every fourth row in the progeny test was planted with commercial Stringless Green Refugee as a check. Several hills on each end of the row were planted with seed saved from early infected plants from the previous year's planting. All test blocks, in addition to having a check row of commercial Refugee every third row, were surrounded by plants grown from seed of infected plants. The fairly uniform spread of mosaic on the checks indicated that the vectors for spread of mosaic were present during the test seasons. Final readings on percentage of infection were made several days after commercial Refugee had reached the canning stage. The reason for the lateness of this reading was to provide ample time for the spread of mosaic under natural conditions. Any plant which showed bean mosaic, whether due to virus No. 1, virus No. 2, (Pierce) or "rugose" mosaic as described by Nelson (2) was counted.

No artificial innoculations, such as described by Fajardo (1) and Pierce (3), were made in either the greenhouse or the field. Some workers believe that, after all, the final test of resistance to mosaic is a field test where the strain is interplanted with, and surrounded by, severely infected plants, and where conditions are favorable for the spread of the virus or viroses. To test the validity of this method, supplementary artificial innoculations will be used purely as a supplement to the field tests.

Further work is contemplated and the complete data will be published at some future date.

The work so far has shown:

1. Only three F_8 progenies out of 22 from a cross of Wells Red Kidney X Refugee Wax showed more than 10 per cent field infection by mosaic (virus 1). Eight of these progenies showed no infection in the field. The average infection of nine Refugee checks was 34.4 per cent.

2. The above family crossed on Green Refugee gave 23 F_4 progenies of which 10 had an infection over 10 per cent. Five progenies had an infection of 5 per cent or less. These F_4 progenies showed more variation for per cent infection than the kidney cross progenies.

3. Only two P_8 progenies out of 17 from the "black seeded selection" showed an infection over 10 per cent. Most of the "lines" from this selection showed a very low mosaic infection in the field. Four large 1934 progenies from a single progeny in 1933 averaged less than

[1]Journal Article No. 198 (n. s.) from the Michigan Agricultural Experiment Station.

5 per cent infection. Common bean mosaic (virus 1) does not reduce the crop on the plants of this selection to the extent that it does on Refugee.

4. Two selections out of Refugee were made in 1931, one from a mosaic-free progeny and the other from one showing 59 per cent infection. After three generations of selection, the averge infection of both lines was essentially the same. There was one oustanding progeny that was mosaic-free in 1931 and 1932 and had 4.6 per cent infection in 1933 and only 2.9 per cent in 1934. The Refugee check in 1933 had 40 per cent and the 1934 check 20 per cent infected plants. Whether this is true resistance or merely escape will be determined by further tests.

5. To determine whether there was segregation among progenies in the F_4 to F_8 generation, pod lengths for 17 progenies were treated statistically by Fisher's analysis of variance method and it was found that:

a. The deviations in mean length of pod among the 17 progenies were highly significant ($F=38.9$).

b. The individual progenies were very uniform within themselves.

c. The differences in mean length of pod among the three families was significant.

d. Some progenies in each family had significant differences when compared with one another. This was more marked among the progenies of the Kidney Cross family crossed on Green Refugee than in the others.

6. Counts on number of pods produced per plant when treated by the same statistical methods as those used for pod length showed:

a. Though there was much variation in number of pods per plant, the deviations between progenies are significant as shown by an "F" of 2.55. These deviations, then, cannot all be attributed to environmental conditions.

b. Three of the four families exhibited no significant differences in number of pods per plant among their own progenies.

c. The Kidney Cross family crossed on Green Refugee showed significant differences between several of its F_4 progenies.

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Relation of Soil Reaction to Potato Yields

By Ora Smith and G. C. Moore, *Cornell University, Ithaca, N. Y.*

Abstract

This paper will be published elsewhere.

Results from Hybridizing Cabbage with Brussels Sprouts[1]

By T. M. CURRENCE, *University of Minnesota, St. Paul, Minn.*

INTERCROSSING of the subspecies of *Brassica oleracea* has not been utilized to the extent which the material justifies. The plant breeding possibilities offered by this group are easily recognized and many of the difficulties which exist in other material are eliminated by the nature of this group of plants. Probably no other group of vegetables is so easy to propagate from seed under so widely varying conditions. Being adapted to growing in limited space, they offer an opportunity to make full use of greenhouses during cold weather and the economic importance of the species will emphasize any progress made toward varietal improvement. The preliminary work which it is desired to present in this paper began as a study of the inheritance of certain distinct characteristics of the two parents and this work is still in progress. However, there are certain phases of the study which are primarily of a plant breeding nature, and include the following possibilities:

1. Improving the eating and marketing quality of cabbage by transferring certain characteristics from the Brussels sprouts.
2. Development of a variety of Brussels sprouts which will be as widely adapted to growing conditions as cabbage. Under Minnesota conditions such a plant would have to tolerate a short summer of relatively high temperatures and long days followed by a short cool fall season.
3. A new type of plant might be obtained which would be a combination of cabbage and Brussels sprouts, which is to say that it would develop one large terminal head and numerous small heads in the leaf axils.
4. A further possibility is the devolping of a cabbage plant which would, as the result of branching, form more than a single terminal head. Such a plant may be considered as the intermediate form of the two parents and would have distinct commercial possibilities.

Previous to the past year the program had been to backcross the F_1 with Brussels sprouts and make selections. Such selections were then self-pollinated and the selection work repeated. This program did not offer results of great encouragement and it was therefore decided to unite the parents and hybrids in various combinations and compare their progenies in producing the selections previously described.

In the winter and spring a number of different crosses were made and the progenies grown during the summer. The plants were somewhat late in developing as a result of drought and insect injury, but at the time the records were taken they were all in normal condition and growing normally. The crosses made and the results obtained from each are shown by Table I.

[1]Paper No. 1331 of the Journal Series of the Minnesota Agricultural Experiment Station.

TABLE I—NUMBER OF SELECTIONS FROM DIFFERENT POPULATIONS

Pedigree	Size of Population	Improved Cabbage	Brussels Sprouts	Combination	Compound Branching
F_2	30	3	0	0	0
F_1 x Savoy Cabbage	37	0	0	0	1
F_1 x Babyhead Cabbage	143	0	0	1	3
F_1 x Brussels Sprouts	236	1	4	3	0
F_1 x Selection 633	138	0	0	3	0
Selection 633 x Cabbage	246	0	0	2	1
Selection 633 x Brussels Sprouts	50	0	0	0	2
Selection 633 Selfed	96	3	1	1	1

The genetic differences between the two original plants do not appear to be great, especially in some of the crosses, but in others there are indications of wide differences. However, it is desired to emphasize the plant breeding information rather than the genetic differences. There are certain conclusions which can be made relative to the types of crosses giving the largest percentage of selections for the different purposes. The small F_2 population produced three promising selections for improved quality cabbage and was the most productive of any of the populations for this type of selection. The F_1 when crossed to Brussels sprouts produced one selection for improved cabbage out of a population of 236 plants. Selection 633 of the previous season when selfed gave three out of a total of 96 plants. (Selection 633 was selected for the combination of cabbage and Brussels sprouts characters.)

There were but two populations which produced Brussels sprouts selections. The F_1 by Brussels sprouts gave four selections in the proportion of one in 59 and selection 633 selfed produced one in 96. It is therefore obvious that backcrossing the F_1 to the sprouts parent provided the most promising material for this purpose.

Most of the populations provided material of promise for the selection of combined characters. The F_1 crossed with the selection produced the greatest percentage being three out of 128 or one in 43. However, the selections which most nearly approached the ideal were those from the F_1 by Brussels sprouts. The proportion of selections in this group was one in 79. The population from selfing 633 was a disappointment in this respect since it had been selected for this group the previous generation. Although the parent plant did not closely approach the ideal, its progeny illustrates the desirability of making genotypic tests before definitely classifying such an individual.

Compound branching with terminal heading was found to occur most frequently in the cross of 633 by Brussels sprouts group, occurring in the proportion of one in 25. The two populations resulting from crossing the F_1 with two distinct types of cabbage provided selections in this group and in about the same proportions, but it is to be noted that for other types of selections the Savoy cabbage did not prove a desirable parent. However, the population being small may account for this. An interesting difference between these two populations was that those from the Babyhead formed about 50 per cent cabbage heads and

the other formed none. Apparently cabbage varieties differ in their relationship to the Brussels sprouts plant.

Based on the data which have been presented, it is thought that future crosses will largely consist of backcrossing the F_1 to Brussels sprouts and possibly using the F_2 for cabbage selections. The F_1 crossed to Babyhead cabbage will also be used to some extent. Final decisions, however, will await the results of testing the progenies of those selections now on hand.

Heating Hotbeds by Five Different Methods

By G. J. STOUT, W. B. MACK, J. E. NICHOLAS, and D. C. SPRAGUE, *Pennsylvania State College, State College, Pa.*

ABSTRACT

This paper will be published elsewhere.

The Effect of Blanching on Quality of Asparagus

By J. P. MCCOLLUM, *Cook County Experiment Station, Des Plaines, Ill.*

ABSTRACT

This material will be published in full elsewhere.

ASPARAGUS blanched by soil and inverted containers was compared with green shoots as to growth rate, chemical composition, and morphological structure. The growth rates of green and container blanched plants, as measured by height of stems, were very similar, and at the end of 6 days were over twice those of the soil blanched shoots. Mean temperatures of the treatments did not vary materially. Green asparagus was higher in dry matter, alcohol insoluble residue, and protein nitrogen, but was lower in total sugars, which are usually associated with flavor, than the soil blanched shoots. In general, the plants blanched by inverted containers were intermediate in composition. The cell walls of the pericyclic fibers, which are primarily responsible for toughness in asparagus, were much thicker in the case of the soil blanched shoots than in those of the other treatments, especially those of the green shoots.

Some Promising Sweet Potato Seedlings and Introductions

By J. H. Beattie, *U. S. Department of Agriculture, Washington, D. C.*

IN connection with the activities of the Foreign Plant Introduction work of the Department, numerous lots of sweet potato material have been received and tested within the past several years. Some of this material was collected wholly on the initiative of plant explorers acting for the Division of Plant Exploration and Introduction, while other material was gathered at the request of the horticulturists of the Bureau of Plant Industry. In some cases such as those of seedling material received from the Virgin Islands, the Division of Plant Exploration and Introduction acted as an introduction agent for the receipt of material previously arranged for. Irrespective of the details employed, several hundred lots of sweet potato material have been received during the past quarter of a century and most of this has been given a careful field trial by the Division of Fruit and Vegetable Crops and Diseases and its predecessors and out of this great mass of material, a few introductions and seedlings have emerged as worthy of possible commercial value. Tests of these materials have been made under varying conditions at the Arlington Experiment Farm, Rosslyn, Virginia; the Horticultural Field Station at Beltsville, Maryland; at Manhattan, Kansas; on the Eastern Shore of Virginia; at Meridian, Mississippi; and elsewhere. Such factors as adaptability to soil and climatic conditions, yielding and keeping ability, resistance to disease, particularly stem rot, and quality have served as a basis for the evaluation of these materials.

Recent work by the Bureau of Chemistry and Soils of this Department in developing methods for the making of sweet potato starch, a material which has been found to be especially suitable for the sizing of fabrics, for laundry work, and for the making of dextrin, has directed renewed attention to sweet potatoes especially suitable for such utilization work. Fortunately, analyses conducted in connection with the testing of the numerous sweet potato introductions and seedlings show that several of these lots are especially high in recoverable starch of high quality. Other tests have been shown a marked resistance to stem rot, even under conditions of severe artificial inoculation. As for the characters of color and appearance, it may be said that at least a portion of these lots are quite attractive and possess some commercial possibilities as market sorts. We will briefly summarize the present status of this work.

For purposes of convenience, the lots discussed in this paper are divided into two groups,—first, several introductions from various parts of the world which are designated, as far as known, by the varietal name attached to them in their native land and, secondly, several seedlings received from the Virgin Islands with designating numbers which, for the present, are retained. Later, a varietal name may be adopted should conditions warrant such an action.

Descriptions of Varietal and Seedling Introductions

Japanese Yam:—Japanese Yam was first grown by the Department at Arlington Farm, Virginia, in 1916. Its history is not clear, but it is supposed to have originated in Japan. The vines are short to medium in length, coarse and green. The leaves are large and green. The roots are broad, tend to be globular and smooth and white. When cooked the flesh is moist, sweet, and of good quality. The variety is a heavy yielder and a good keeper. It contained 23.35 per cent of recoverable starch. It is only moderately resistant to stem rot. It is believed that it has value for starch-making and possibly as a market sort.

Mameyita:—This variety was received in 1919 from Professor T. B. McClelland, Horticulturist, Porto Rico Agricultural Experiment Station, Mayaguez, Porto Rico. It has medium length, stocky, coarse, greenish-purple stems, green foliage with the lower veins purple and a purple stain at the summit of the petiole. The roots are large, broad to ovoid, smooth with salmon skin, and deep salmon flesh splashed with red. Its season is early. It is a moderately heavy yielder, a good keeper and of excellent quality. In appearance it is somewhat like the Porto Rico, yet more regular and of a richer color. Unfortunately it seems to be quite susceptible to stem rot. In starch content it is about the same as Nancy Hall. On account of its excellent qualities, it is believed to have commercial possibilities, especially as a market sort.

Oebi Saboelan:—This variety was received from Mr. L. Koch, Department of Agriculture, Buitenzorg, Java, in 1926. It is characterized by stocky, coarse, bunch-like green foliage. The leaves are shouldered and green. The roots are long, cylindrical, smooth, with light-colored skin and salmon-colored flesh. Its season is early. It is a heavy yielder, an excellent keeper, quite resistant to stem rot, and relatively high in starch (21.6 per cent by physical recovery).

Kioranda Dutch Yellow:—Stock of this variety was obtained in Japan in 1930 by Messrs. P. H. Dorsett and W. J. Morse of this Department from the Saitama Agricultural Experiment Station at Urawa. The variety is characterized by medium length, coarse, purple vines with green petioles and with a purple stain at the base of the leaf and has shouldered green leaves of medium size. The roots are globular to ovoid, smooth, of cream color with ivory flesh flecked with deeper color. The flesh is moist and sweet when cooked and of high quality. The variety is an excellent keeper, a heavy yielder, and highly immune to stem rot. One set of analyses, the only ones thus far made, showed over 22 per cent of recoverable starch. On the basis of quality, this variety should be of importance. Its only drawbacks are its light-colored skin and tendency to grow to large size.

Menes Moeder:—This variety was sent to the Department by Dr. Crane of the Java Experiment Station at Buitenzorg, Java, in 1923. It has thick, coarse vines, 4 to 5 feet long, with large-shouldered green leaves with a purple stain at the base of each leaf. The roots are smooth-skinned, broad, globular, orange to salmon in color with rich salmon flesh. It is moist and sweet when cooked. Yields have been moderately heavy. It has most excellent quality, marked resistance to stem rot, and it is a fairly good keeper.

Seedling 254:—This is an open-pollinated seedling of the Big Wig variety grown at the Virgin Islands Experiment Station in 1922. Roots of this seedling were received by this Department in 1923 and it has been grown in our trials since that time.

It has coarse, short, green stems with large, deeply cut, green to greenish-purple leaves borne on long green petioles. There is a purple stain at the base of the leaf blade. The roots are long, irregular and veined. The skin is purple and the flesh white. It is a moderate yielder, an excellent keeper and, when cooked, the flesh is moderately soft and very sweet. The quality is excellent. In laboratory infection tests, this seedling was entirely resistant to stem rot. The color and irregularity of this seedling are objectionable but its resistance to stem rot and its high starch content (22.7 per cent by physical recovery) make it worthy of careful study.

Seedling 291:—This seedling is likewise from the Virgin Islands Experiment Station, of Big Wig female parentage. It reached the Department of Agriculture in 1923 and has been grown in our trials since that time. The vines are short, coarse, and green. The foliage is small, deeply lobed and green. The veins on the upper leaf surface are green, on the lower surface purple. There is a purple stain at the base of the leaf. The petioles are 10–12 inches long and green. The roots are long and irregular, red to purple, and the flesh is white. It is a moderately heavy yielder and a good keeper. This seedling is moderately resistant to stem rot. The flesh is moist when cooked, very sweet, and of good quality. Its chief promise would seem to be for utilization purposes, such as starch-making and for growth under severe stem rot conditions, since its shape and color are objectionable from a market standpoint.

Discussion and Summary

The marked resistance of many of these lots to stem rot caused by *Fusarium batatatis* Wr. and *F. hyperoxysporum* Wr. makes it particularly desirable to test them more extensively for commercial culture under severe stem rot conditions. Moreover, breeding work to incorporate this resistance into our established commercial varieties has great promise and such work is now being undertaken in cooperation with the Department of Agriculture, Santiago De Las Vegas, Province of Havana, Cuba. The most important prospective use for these lots is, however, for the making of sweet potato starch and dextrin. Through the work of the Bureau of Chemistry and Soils of this Department, methods have been devised for the making of a grade of sweet potato starch that is especially suitable for textile work. Moreover, the making of dextrin from sweet potatoes for uses as an adhesive has also developed from this work. Several of the introductions and seedlings discussed in this paper contain much higher proportions of recoverable starch than is the case with the commercial varieties now available. No effort is being made to introduce these lots as commercial sorts until they fully prove their possibilities under varying conditions. It should be stated that only small experimental quantities of these lots are as yet available. Commercial plantings, if desirable, will have to await the gradual increase of the seed stock.

Methods in Variety Trials

By WARREN B. MACK, *Pennsylvania State College, State College, Pa.*

ABSTRACT

This paper will be published in full elsewhere.

VARIETY trials are an unavoidable part of the work of the plant breeder and of the vegetable specialist in research or extension, and it is essential that they be efficiently conducted and correctly interpreted. Because yielding capacity, although highly important, is one of the most difficult characteristics to measure with any degree of certainty, but little attention should be paid to data on yield in ordinary variety or strain comparisons. This fact was brought out by an analysis of yield records in tomato strain tests which were carried on at the Pennsylvania Agricultural Experiment Station by several methods through four seasons. In certain of these trials, in which yields were recorded for each of 25 plants in each strain, in single plots, the minimum difference in total yield between two strains which was significant was approximately 20 per cent of their mean; in the yield of early fruit, or that produced during the first three weeks after harvesting was begun, differences of 40 per cent were required to be significant, and in yields of marketable fruit, 33 per cent. By this method, it was impossible to know how much of the difference may have been due to soil variability. In another season, 30 plants of each variety were planted in five plots of six plants each, and plots were distributed so that no two of a given variety occurred in the same one-fifth of the field, as divided by equidistant lines either parallel with the long dimensions of the plots and across the entire field, or at right angles to such lines. With this plan, differences in total yield of 25 per cent, and in early yield of 37 per cent were required to be significant.

Type studies, ordinarily conducted in addition to yield measurements in variety trials, must be placed on a quantitive basis if comparisons of strains are to be made. It was found by studies made during 1934 that type analyses on dwarf stringless bean pods gave results which were subject to rather small errors, when several random samples, taken from widely separated sections in rows 275 feet long, were classified as to percentage with typical form, even when the definition of typical form was rather loose. In these studies, samples of 100 to 150 pods which were ready to harvest were taken, either from baskets as they were brought in by pickers, or by picking all of the mature pods along the row until a sample of that size had been collected. Limits of typical form were laid down arbitrarily, and the percentage of the whole number of pods which fell within the limits was estimated. In strains which had from 40 to 50 per cent of typical pods, successive samples did not differ from each other by more than 5 to 7 per cent. Type strains with beets and carrots, with random samples of 20 plants, resulted similarly. In these studies, all roots were classified as to form, by counting those of each characteristic form; as to size, by establishing size classes based on transverse diameter of the

edible portion; as to shade of color, by establishing arbitrary light, medium, and dark classes; as to zoning of beets or corelessness of carrots; and as to relative size of tops. Repeated sampling of a given strain gave quite similar results, even with the relatively small number of plants in a sample.

It is indicated that type studies on a quantitive basis constitute a practical method of comparing vegetable varieties.

Anatomy of the Carrot Root

By Ora Smith, and H. L. Cochran, *Cornell University, Ithaca, N. Y.*

Abstract

This paper will be published elsewhere.

Morphology of an Internal Type of Abnormality in the Fruit of the Pepper

By H. L. Cochran, *Cornell University, Ithaca, N. Y.*

Abstract

The original paper will be published in the Botanical Gazette.

The internal type of abnormality has its origin in the subepidermal layer of the placenta when the pepper bud ranges from 1 to 3 millimeters in diameter. It develops simultaneously with the ovules and approximates them in many respects but for only a limited time. Early in the ontogeny of the abnormality it can be detected as a mass of undifferentiated lightly stained cells. Soon after this stage, however, the epidermis is differentiated.

The tissue of the abnormality and that of normal placental tissue are anatomically the same. Both have thin walled parenchyma cells that take like stain reactions and are capable of initiating and developing ovules. Only one ovule from within the abnormality was found in the megaspore mother cell stage and none any further advanced than the 2-celled embryo sac stage.

As far as could be detected, the abnormality is always initiated as a single protuberance and may develop as such, but frequently branches into secondary and even tertiary parts. For this reason, no definite shape can be assigned the malformation.

Summary of Performance Records of Individual Plants of Mary Washington Asparagus

By G. C. Hanna, *University of California, Davis, Calif.*

INDIVIDUAL plant performance records on Mary Washington at Davis, California, and at Ryer Island show a wide variation in yield, average weight of spear, cross section, shape, earliness, compactness of head, and color.

The variation in yield ranges from practically nothing to 700 or 800 per cent of the average. Schermerhorn (1) has also found a wide variation in yield in Martha Washington and Palmetto in New Jersey. Five years' records show that some plants are always low in yield, while others are high. Some plants only produce large spears, others small, while some plants produce the entire range from very small to large spears. Among the low yielders, the most general type is one that has only a few large spears. Females predominate in this group. Another group, in which males predominate, yields a large number of small to medium size spears. The highest yielding plants are those which produce many medium to large spears. They are mostly males, although some high producing females have been found.

The cross section shape of the spears on a plant varies to some extent but fluctuates closely around a mean. Some plants produce practically round spears, while others have more or less flattened spears. Many of the flattened spears have a hollow center and are objectionable to the canner.

Some plants start producing early in the spring, while others start late. Very early plants are predominately males, while the late ones are mostly females, although both sexes are found in each class. This agrees with the work of numerous investigators who have found male plants to be earlier than female.

Compactness of the head is another variable character. As the season advances and the daily temperature increases, the heads become less compact at any given distance above the soil surface. Females tend to have tighter heads than males.

The color of the spears of Mary Washington ranges from a light to a dark green with a purple overcast. As the season advances the overcast becomes somewhat faded. For production of white asparagus, plants with a purple overcast are undesirable, as the tips turn purple just as, or even before, the spears emerge from the soil, and from such plants a pure white product cannot be obtained. Canning tests have revealed that such plants have a stronger flavor and are more bitter than the lighter colored types.

For the canning industry, a high yielding plant with spears medium in size, round in cross section, having compact heads with closely adhering scales, and a green color without a purple overcast is most desirable.

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The Effect of Plant Spacing on the Development of Sweet Potato Storage Roots

By H. H. Zimmerley, *Virginia Truck Experiment Station, Norfolk, Va.*

THERE is considerable diversity of opinion among sweet potato growers as to the optimum spacing of plants in the row from the standpoint of yield and quality. However, it is a generally accepted fact among growers on the Eastern Shore of Virginia that for rapid development of storage roots for early market the wider spacings, 20 to 24 inches, are most suitable. It has also been noted that wide spacing is productive of a large percentage of oversized roots if the harvest of early planting is delayed until October. Even with relatively close spacing it has been found that plants adjacent to vacant places in the row, due to irregular stands, produce a high percentage of "jumbos" which are frequently unmarketable.

Experiments were started in 1934 with the Porto Rico variety at the Virginia Truck Experiment Station at Norfolk and with the Little Stem Jersey variety at the Eastern Shore sub-station at Onley, Virginia, in order to furnish growers with information regarding the effect of different distances of spacing in the row on yield and quality. The experimental area at Onley was located on a Sassafras fine sandy loam and at Norfolk on a Sassafras loam soil. The rows were spaced 30 inches apart in both experiments, with four rows to a plat. The plats at Onley were 100 feet in length with four replications. One thousand pounds per acre of a 3–3–15 fertilizer was applied after the plants had been set. The spacings of the plants in the row were 12, 16, 20, and 24 inches at Onley and 10, 14, 18, and 22 inches at Norfolk, in order to conform to spacings used by commercial growers in these respective sections. The plants were set on May 28, 1934 at Norfolk, on June 7, 1934 at Onley, and harvested on October 18 and October 30, respectively.

Individual hill records were obtained from 50 plants from the two inner rows of each plat. The roots were graded according to the U. S. Standard grades for sweet potatoes. Those with diameter below 1¾ inches were classed as culls, with diameters between 1¾ and 3½ inches as U. S. No. 1 or Primes, and with diameters in excess of 3½ inches as jumbos.

Data regarding the effect of spacing on the average number of storage roots for each plant and the average weight of each root is given in Table I. In every instance, increasing the space between plants resulted in an increase in the average weight of each root and, with one exception, in an increase in the average number of roots to the plant.

The number of primes to the plant increased with an increase in spacing from 10 inches to 14 inches and 14 inches to 18 inches. Increasing the planting distance from 20 inches to 24 inches did not result in a significant difference.

The average weight of each root of primes increased with each increment increase in spacing. The effect of increased spacing on size

TABLE I—THE EFFECT OF SPACING ON NUMBER AND SIZE OF SWEET POTATOES

Spacing in Row (In.)	Primes (U. S. No. 1)		Culls		Jumbos		Total	
	Number per Plant	Average Weight per Root (Gms)	Number per Plant	Average Weight per Root (Gms)	Number per Plant	Average Weight per Root (Gms)	Number per Plant	Average Weight Per Root (Gms)
Porto Rico Variety—Norfolk, Virginia								
10	2.83±.08	188.4±4.0	4.00±.13	43.2±1.2	.06±.02	477.5± 6.6	6.89±.16	107.4±3.3
14	3.45±.08	200.1±3.2	4.84±.17	45.5±1.0	.10±.02	597.4± 5.9	8.39±.19	115.6±2.5
18	3.73±.09	208.0±3.73	4.37±.13	45.3±1.0	.21±.03	542.4±12.1	8.31±.14	130.7±2.8
22	3.69±.10	220.5±4.83	4.87±.16	40.2±1.0	.44±.04	558.7±15.5	9.00±.31	139.7±4.1
Little Stem Jersey Variety—Onley, Virginia								
12	2.71±.08	183.1±4.0	4.94±.15	39.2±1.0	—	—	7.65±.15	90.8±2.2
16	2.83±.08	196.1±3.2	5.39±.16	46.4±1.0	—	—	8.22±.17	99.2±2.3
20	3.64±.08	204.3±3.0	4.91±.15	45.2±1.0	—	—	8.45±.18	114.5±2.2
24	3.67±.09	211.8±3.8	5.44±.18	47.3±.09	—	—	9.11±.20	114.9±2.9

of roots is shown in the definite increase in number of jumbos (diameter in excess of 3½ inches), in the Porto Rico variety, where the number per hill doubled with each four inch increase in distance between plants.

The average weight of primes for each plant was .53, .69, .77, and .81 kgs, and the total weight for each plant was .74, .97, 1.08, and 1.15 kgs, respectively, for the 10-14-18- and 22-inch spacings of the Porto Rico variety. With the Little Stem Jersey variety the average weight of primes for each plant was .5, .56, .74, and .78 kgs, and the total weight for each plant was .69, .82, .97, and 1.05 kgs, respectively, for the 12-16-20 and 24-inch spacings.

The increased yield for each hill, however, did not compensate for the increased area allotted each plant.

On the basis of the area to each plant the efficiency ratings of the different spacings were 100, 93, 82, and 70, respectively, for the yield of primes, and 100, 97, 86, and 81, respectively, for the total yield for the 10-14-18- and 20-inch spacings. With the Little Stem Jersey variety the ratings were 100, 90, 96, and 83 for yield of primes, and 100, 94, 95, and 80, respectively, for the total yield of the 12-16-20- and 24-inch spacings.

The calculated yield on the acreage basis (Table II) shows that the closest spacings gave the highest yield of marketable sweet potatoes and also the highest total yields. The yield of the Porto Rico variety for the 10-inch spacing was not significantly greater than that of the 14-inch, but yields from both the 10-inch and the 14-inch spacings were significantly greater than those obtained from the wider planting distances.

TABLE II—Calculated Yield in Bushels to the Acre for Different Spacings

Spacing (In.)	Primes (Bus. per Acre)	Culls (Bus. per Acre)	Jumbos (Bus. per Acre)	Total (Bus. per Acre)
		Norfolk		
10	433	142	23	580
14	403	129	34	566
18	355	90	53	498
22	303	74	92	469
		Onley		
12	316	120	—	438
16	284	127	—	411
20	304	114	—	418
24	264	86	—	350

The 12-inch and the 20-inch spacings gave maximum yields for the Little Stem Jersey variety, but the differences in yield between the 12-16- and 20-inch spacings were not significant. The yield to the acre from the plants set 24 inches apart was significantly less than from those set at lesser distances apart.

The writer recognizes the fact that data obtained with this type of an experiment is largely influenced by other environmental factors

as supply of available nutrients, rainfall, temperature, soil type, period of growth, etc., and should be repeated a number of years before drawing definite conclusions. However, on the basis of the results in 1934 it appears that the 14-inch spacing is optimum for the Porto Rico variety for late harvest, and the 20-inch spacing for the Little Stem Jersey variety, provided the grower has sufficient plants to set the desired area at this distance.

Where scarcity of plants is a limiting factor it may be advisable to use wider spacings because the yield of primes per plant increases slightly with the wider planting distances. Wider spacing, however, involves additional expenditure for hoeing and cultivation and utilizes land which might be used for other purposes.

Effect of Temperature on Rate of Pollen Tube Growth in the Tomato

By ORA SMITH and H. L. COCHRAN, *Cornell University, Ithaca, N. Y.*

ABSTRACT

This paper will be published elsewhere.

Correlation Between Vigor and Doubleness in Stocks

By S. L. EMSWELLER, *University of California, Davis, Calif.*

ABSTRACT

This paper will be published in the Hilgardia series.

Some Factors Influencing the Rooting of Cuttings of the Chinese Holly (*Ilex cornuta*)

By C. C. THOMAS, *U. S. Department of Agriculture, Washington, D. C.*

ABSTRACT

This material will be published in full in the Nat. Hort. Mag. 14: No. 2. 1935.

THE influences of the media in which the cuttings are placed, the time of taking them, and the type of cutting are considered. When the proper combination of these factors is used it is possible to root a high percentage of the cuttings of *Ilex cornuta* in 2 to 3 weeks instead of the usual 3 to 4 months, or longer.

The Effect of the N-P-K Fertilizer Ratio on the Shape of the Porto Rico Sweet Potato

By H. H. Zimmerley, *Virginia Truck Experiment Station, Norfolk, Va.*

SWEET potato fertilizer studies have been conducted by the Virginia Truck Experiment Station on plats receiving the same continuous treatment during the past 15 years. The proportions of ammonia, phosphoric acid, and potash in each of the 15 different mixtures were determined by the "triangle" method. Each was a complete mixture containing a total of 21 units of nutrients in 3 per cent gradients. They were used at the rate of 1,000 pounds per acre for sweet potatoes.

Until 1932 no attempt was made to ascertain the effect of treatment in this experiment on root shape. That year Carolus (1) measured roots of the Porto Rico variety and found that there were no consistent significant differences which would indicate the superiority of one fertilizer mixture over another in the production of the short, thick type of storage root. In comparing his results with those obtained by Schermerhorn (4) he stated that apparently the shape of the Porto Rico variety has normally a low L/D ratio and is less readily influenced by nutrient conditions than is the Yellow Jersey. The writer's observations also have been that the Porto Rico roots are usually of a chunky type irrespective of fertilizer treatment. However, in obtaining the 1934 yield records it was noted that the roots were especially long on the plats treated with high percentages of phosphorus and low percentages of nitrogen and potassium.

In order to determine the relationship between fertilizer treatment and shape of roots, measurements were made of the length and diameter of 160 roots from each plat. Roots were selected at random from the barrels containing the U. S. Standard No. 1 grade. Measurements were made with an especially prepared caliper. The length of root was obtained from that portion larger than 1.5 cm, in diameter. A summary of the data on shape and yield is given in Table I. A low L/D ratio indicates a chunky type of potato and a high L/D ratio a relatively long one.

There is a variation of 50 per cent between the lowest and the highest ratio. Length rather than diameter appears to be in general the factor determining variations in the ratio. The L/D ratio increases consistently with few exceptions with increase in length while there is no consistent decrease in diameter. In general the highest yields are associated with the lowest L/D ratios.

The different treatments have been so grouped in Table II that the effect of two variables on the L/D ratio may be more readily noted. In the Section 1 where equal ammonia percentages are compared the ratios of high potash to low phosphorous have given significantly lower L/D ratios than did the high phosphorous and low potassium combinations. In Section 2 where equal potash percentages have been compared, high ammonia to low phosphorus ratios have, with one exception, given significantly lower L/D ratios. These comparisons

TABLE I—ROOT SHAPE IN THE PORTO RICO SWEET POTATO ARRANGED ACCORDING TO THE ASCENDING ORDER OF LENGTH/DIAMETER RATIO

Fertilizer	Length/ Diameter Ratio	Diameter (Cms)	Length (Cms)	Plat* Yield (Kgms)
9–3–9	1.80±.062	6.54	11.77	405
6–3–12	1.99±.037	6.80	13.53	422
3–6–12	2.01±.037	6.57	13.20	408
12–3–6	2.07±.039	6.58	13.62	370
3–3–15	2.19±.038	6.20	13.58	367
6–9–6	2.20±.040	6.27	13.79	371
9–6–6	2.23±.039	6.46	14.41	363
9–9–3	2.25±.028	6.38	14.35	307
6–12–3	2.26±.026	6.27	14.17	308
15–3–3	2.27±.034	6.85	15.55	233
6–6–9	2.29±.041	6.60	15.11	342
12–6–3	2.31±.034	6.53	15.08	278
3–9–9	2.36±.033	6.20	14.43	338
3–12–6	2.44±.047	5.83	14.22	295
3–15–3	2.71±.047	6.09	16.50	209

*Plat size 1/20 acre.

indicate that both nitrogen and potash tended to produce a chunky type root while phosphorous had the opposite effect on shape.

The relative effect of nitrogen and potassium in decreasing the L/D ratio is shown in Section 3. Apparently the higher percentages of potash are more effective than the higher percentages of nitrogen in decreasing the L/D ratio, while the opposite is true with the lower percentages (6 per cent and 9 per cent). In only one instance, where the 3–6–12 and the 12–6–3 formulae were compared, were the differences particularly significant.

The fact that the lowest ratios were obtained with the 9–3–9 and the 6–3–12 mixtures indicates that an abundance of nitrogen as well as potassium was needed for the production of the thick type of root. This is in agreement with the work of Nightingale (2) and Robbins (3) who found that an ample supply of nitrogen as well as potassium was needed to accelerate cell division in the direction of the diameter.

It is difficult to accurately evaluate the effect of phosphorus on shape. Average L/D ratios for the different percentages of nutrients in Table III indicate that phosphorus plays an important part in increasing the relative length of the storage roots. There is a consistent increase in the L/D ratio with an increase in the percentage of P_2O_5 in the mixture. However, this increase may be due to decreasing amounts of NH_3 and K_2O as the percentage of P_2O_5 increases.

TABLE III—AVERAGE L/D RATIOS WITH DIFFERENT PERCENTAGES OF NUTRIENTS

Nutrients	3 Per cent	6 Per cent	9 Per cent	12 Per cent	15 Per cent
NH_3	2.34	2.19	2.09	2.19	2.27
K_2O	2.36	2.24	2.15	2.00	2.19
P_2O_5	2.06	2.21	2.27	2.35	2.71

TABLE II—THE RELATION OF THE INGREDIENTS IN THE FERTILIZER MIXTURE TO THE LENGTH/DIAMETER RATIO

Section 1			Section 2			Section 3		
Potassium Compared with Phosphorus			Phosphorus Compared with Nitrogen			Potassium Compared with Nitrogen		
Fertilizer	Difference of L/D Ratios	Significance of Difference in Odds	Fertilizer	Difference of L/D Ratios	Significance of Difference in Odds	Fertilizer	Difference of L/D Ratios	Significance of Difference in Odds
3-3-15 3-15-3	2.19±.038 2.71±.047		3-15-3 15-3-3	2.71±.047 2.27±.034		3-3-15 15-3-3	2.19±.038 2.27±.034	
	—.52±.06	Inf.		+.44±.058	1,000,000:1		—.08+.05	1.6:1
6-3-12 6-12-3	1.99±.037 2.26±.026		3-12-6 12-3-6	2.44±.047 2.07±.039		3-6-12 12-6-3	2.01±.047 2.31±.034	
	—.27±.044	20,000:1		+.37±.061	20,000:1		—.30±.058	1,000:1
9-3-9 9-9-3	1.80±.062 2.25±.028		3-9-9 9-3-9	2.36±.033 1.80±.062		3-9-9 9-9-3	2.36±.033 2.25±.028	
	—.45±.068	20,000:1		+.56±.071	Inf.		+.11±.043	12:1
12-3-6 12-6-3	2.07±.039 2.31±.034		3-6-12 6-3-12	2.01±.037 1.99±.037		3-12-6 6-12-3	2.44±.047 2.26±.026	
	—.24±.052	7,500:1		+.02±.052	1:1		+.18±.054	37:1

The fact that the data obtained by Carolus in 1932 and the observations made during the past 12 years seldom showed any marked effect of fertilizer treatment on root shape, indicates that other factors also influence the shape of sweet potato roots. The amounts of nutrients already in the soil, loss of soluble materials by leaching during periods of heavy rainfall, unavailability of certain nutrients during periods of prolonged drought, physical conditions of the soil, and other factors may also possibly influence shape.

Therefore, it is doubtful whether the commercial grower can expect to consistently control shape within rather narrow limits by fertilizer treatment. However, since the Porto Rico variety is frequently too chunky to meet the market requirements it appears advisable for growers to avoid the use of fertilizers carrying high percentages of both nitrogen and potash.

Since experimental evidence over a period of 15 years has shown that a high potash content is essential for high yields, it appears advisable to recommend a fertilizer with a relatively low nitrogen and a high potash content. The data at hand does not clearly indicate the effect of phosphorus on yield and shape in the presence of a high potash content.

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The Influence of Planting Date on the Shape of the Nancy Hall Sweet Potato

By J. B. Edmond, *Mississippi State College, State College, Miss.*[1]

AT the Louisiana Station, Miller and Kimbrough (1) found a marked difference in the shape of roots produced on early and late planted sprouts of the Porto Rico sweet potato. Sprouts set in the field May 6 and April 20 produced significantly shorter and wider roots than those set July 15 and June 15 in 1932 and 1933, respectively. This lesser length and greater width resulted in a lower length/width ratio for the early planted lots. On the assumption that similar seasonal differences in time of planting would similarly influence the shape of the roots of the Nancy Hall, early and late planted sprouts were grown in 1934 on the Horticultural Farm, State College, Mississippi.

On February 22 certified seed, varying from 3.0 to 7.0 inches long and from 1.0 to 2.0 inches wide, were bedded 1½ inches deep in a 6-inch layer of river bed sand in a raised bench in a greenhouse. Bottom heat was supplied by an electric cable situated about five inches below the surface of the sand. Because of variations in the availability of the electric current, the heating effect of sunshine and the cooling effect of necessary applications of water, temperature within the bed fluctuated between 65 and 90 degrees F.

Two planting dates, April 26 and June 11, were compared. For the April 26 planting sprouts were pulled on March 29 and for the June 11 planting on April 12, 19, and May 3. At the time of pulling and until field setting both lots were heeled in sand, watered when necessary, and given an occasional dose of nitrogen to prevent excessive yellowing of the foliage.

The sprouts were set 14 inches apart in rows 42 inches apart in a somewhat eroded, moderately fertile Oktibbeha clay loam. The early planted lots were set in the south half and the late planted lots in the north half of the experimental plot. At the time of soil preparation a 4–8–4 mixture was uniformly applied in the furrow at the rate of 400 pounds per acre. During the growing season the same number of cultivations and hoeings were given on both lots. The early planted lot was harvested on September 29 and the late planted lot on November 10.

To obtain an index to root shape measurements were made on the length and width of both marketable and unmarketable stock. Length was measured from the point on each end of the roots which first attained the diameter of ½ inch (estimated). Width was measured perpendicular to and midway between the ends of the long axis and in case of flat roots on the more narrow diameter. Measurements were made on a 12-inch rule mounted on a 1¾-inch strip. Readings were made to the nearest ½ inch.

The ratio of the length and width was calculated and is used as an index to root shape. A comparatively large ratio indicates an elon-

[1]The writer is indebted to Dr. C. Dorman, Soils Section, Mississippi Agricultural Experiment Station for reading the manuscript.

gated root and a comparatively narrow ratio a roundish or chunky root. Both the arithmetic mean (M_a) and the geometric mean (M_g) of individual ratios were calculated. A difference between corresponding means greater than three times its probable error is considered significant.

TABLE I—INFLUENCE OF PLANTING DATE ON THE SHAPE OF THE NANCY HALL SWEET POTATO, 1934

Planting Date	Number Roots	Average Measurement (Ins.)		M_a*	M_g**
		Length	Width		
April 26......	1116	3.95	2.21	1.878±.0123	1.607±.0123
June 11.......	644	4.19	1.89	2.479±.0304	1.995±.0320
Difference (April 26 minus June 11)......		—0.24	0.32	†—0.601±.0328	†—0.388±.0343

*Arithmetic mean of individual ratios.
**Geometric mean of individual ratios.
†Differences are considered significant.

The data presented in Table I show that sprouts set in the field on April 26 produced roots possessing a lesser length and a greater width than those set in the field June 11. This correspondingly lesser length and greater width resulted in a lesser length/width ratio for the roots produced on sprouts set at the earlier date. Though a lesser number of roots were measured for the late planted lot, the probable error of its means indicates that late planted lots possessed a greater variability than the early planted lots.

In general, these results agree with those of Miller and Kimbrough (1). These investigators found that sprouts planted early produced rounder, chunkier, and less elongated roots than those planted comparatively late. Our results, however, are not strictly comparable. Miller and Kimbrough measured U. S. No. 1 grade only, and the writer measured all grades. Despite this incomparability, these results indicate that planting date influences the shape of the roots of both varieties in much the same way.

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The Influence of Size of Seed Stock on Plant Production of the Nancy Hall Sweet Potato

By J. B. EDMOND, *Mississippi State College, State College, Miss.*[1]

ON February 22, 1934, two lots were selected from certified Grade A seed of the Nancy Hall sweet potato, one of large roots and one of small roots. The large lot averaged 13.0 cms long and 4.3 cms wide, and the small lot averaged 11.7 cms long and 3.3 cms wide. Their weights averaged 110.2 and 51.2 grams, respectively. Each lot was divided into three sub-lots, each of which consisted of 20 roots. One lot was planted whole, the second cut crosswise into approximately equal halves, and the third with about 5 grams of the proximal end removed.

Bedding consisted of plunging each potato or portion of potato 1½ inches below the surface of a 6-inch layer of river bed sand in a raised bench in a greenhouse. Heat was supplied by an electric cable placed about 5 inches below the surface of the sand. Because of variations in the availability of the electric current, the heating effect of sunshine, and the cooling effect of necessary applications of water, temperature within the bed fluctuated between 65 and 90 degrees F.

Harvesting began on March 22 and continued at weekly intervals, April 26 omitted, until May 3. At this time sprout production had practically ceased. Plants were pulled singly, counted, and weighed for each lot collectively. Before weighing they were shaken lightly to remove sand adhering to the roots. In general, the plants had short internodes, thick stems, and light green leaves. They were stocky in appearance.

Since growers for early market desire large yields of plants during the early production period, the data presented in Table I are arranged to permit comparison of early plant production (first two pullings) with total plant production (all pullings). The figures show that for both periods though the larger roots produced a greater number of plants per root, with the exception of the roots halved crosswise for the early period, the smaller roots produced the greater number of plants per bushel and required a lesser amount of root to produce unit weight of plant. In other words, within the limits of size of the seed stock used in this experiment, with the exception of the early yield of the roots halved crosswise, small potatoes yielded more plants per bushel and were more economical per unit weight of plant produced than large potatoes. Similar results have been secured by Beattie and Thompson (1) and by McGinty and Miller (2) with the Porto Rico variety. However, Beattie and Thompson (1) point out that though from the standpoint of numbers the use of small potatoes is more economical than the use of large potatoes, no definite recommendations can be made until information is available on the

[1]Under the direction of the writer the senior class in Horticulture outlined the experiment and collected the data in partial fulfillment of the requirements in Advanced Vegetable Gardening. The writer is indebted to Dr. C. Dorman, Soils Section, for reviewing the manuscript.

TABLE I—INFLUENCE OF ROOT WEIGHT ON PLANT PRODUCTION OF THE NANCY HALL SWEET POTATO, 1934

Root Treatment	Mean Weight Roots (Gms)	Number Plants per Root*	Mean Weight Plant (Gms)	Gms Root per plant*	Gms Root per Gm plant*	Plants per 56-Pound Bushel*
First Two Pullings (March 22 and March 29)						
Cut crosswise in two equal	52.8	1.70	2.23	31.06	13.93	819
parts..................	111.2	5.50	2.21	20.22	9.15	1257
Removal of proximal end†	52.6	4.80	2.54	10.96	4.31	2320
	115.9	5.55	3.09	20.85	6.75	1219
Not cut	48.2	4.65	2.67	10.37	3.88	2452
	103.4	7.60	2.64	13.61	5.16	1868
All Pullings (March 22 to May 3)						
Cut crosswise in two equal	52.8	8.25	2.17	6.40	2.95	4224
parts..................	111.2	14.20	2.25	7.83	3.48	3247
Removal of proximal end†	52.6	8.00	2.36	6.58	2.79	3864
	115.9	11.20	2.98	10.35	3.47	2456
Not cut	48.2	8.90	2.62	5.42	2.07	4691
	103.4	12.50	2.64	8.27	3.13	3074

*Based on original 20 roots per treatment.
†Determined by inspection only.

comparative vigor and producing capacity of plants from small and large roots.

Results on the cutting treatments are somewhat variable in some cases and quite consistent in others. For the period of early production and for the small roots, though the whole and proximal-end-removed roots produced approximately the same number of plants per root and per bushel, the whole stock required less weight of tissue to produce unit weight of plant. Halving the small roots considerably decreased early sprout production and considerably increased the weight of root to produce unit weight of plant. Apparently, severe cutting of small roots (50 grams or less) lowers their capacity to produce early sprouts. For the large size, whole roots alone produced the more plants per root and per bushel. As in the case of the small size, they required less weight to produce unit weight of plant.

For the period of total production and for the small size, whole roots produced slightly more plants per root and somewhat more plants per bushel than the cut roots. As in the case of both sizes for the early production period, whole roots required lesser amounts of tissue to produce unit weight of plant than the roots with proximal-end-removed and those halved crosswise. For the large size, though, the roots cut crosswise produced more plants per root and per bushel than the whole roots or those with proximal-end-removed, and likewise whole roots required less weight of tissue to produce unit weight of plant.

At this point it should be stated that the data are based on the number and weight of the original stock bedded. At the termination of the experiment, examination was made on the soundness of the bedded stock. More roots of the halved stock had decayed than the proximal-end-removed or whole stock. These decayed roots undoubt-

edly produced few, if any, sprouts. The examination showed 14 and 11 per cent decayed roots for the small and large halved stock and none to five per cent decayed roots for small and large proximal-end-removed and whole roots, respectively.

To summarize briefly: On the number of grams of root-per-gram plant basis, regardless of the root treatment, small roots were more economical than large roots; and regardless of size, whole roots were more economical than those halved crosswise or with proximal-end-removed.

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The Effect of Temperature, Photoperiod and Nitrogen Level Upon Tuberization in the Potato

By H. O. WERNER, *University of Nebraska, Lincoln, Neb.*

ABSTRACT

The complete paper is being published in the American Potato Journal as Journal Paper No. 160 of the Nebraska Agricultural Experiment Station.

TUBERIZATION occurs in the potato only when carbohydrates accumulate in excess of the requirements of the plant for growth and respiration. In the final analysis it is a measure of the relative rates of nitrogen assimilation and carbohydrate synthesis and tuberization.

The occurrence of tuberization in the potato was found to be accelerated by the use of short days, low temperatures or a restricted nitrogen supply with each applied either singly or in combination. It could be induced at temperatures generally considered too high for tuberization (i. e. 85 degrees F) by the use of a short photoperiod or by reducing the external nitrogen supply. Total production of tubers per plant was greater under conditions favoring somewhat more extensive vegetative growth but this resulted in the lower tuber/top ratio. When conditions were favorable for the most extensive vegetative growth tuberization was greatly delayed or did not occur at all. The number and extent of stolons and the number of tubers increased as conditions were increasingly more favorable for vegetative growth. A relatively constant temperature was less favorable for tuberization than one fluctuating diurnally but with the same mean. Whenever the environment was altered tuberization was increased or decreased according to the extent that carbohydrates accumulated when not needed in the synthesis of organic N compounds or for respiration. Under conditions favoring earlier tuberization as contrasted with those less favorable there was a higher tuber/top ratio, tubers were fewer but larger with a higher percentage of dry matter, and stolons were shorter, less numerous and thinner.

As tubers developed, a continually increasing percentage of the assimilated nitrogen of the plant was found in the tubers till finally it was translocated from the tops to the tubers. Tubers assimilated extensive amounts of nitrogen when none was being assimilated by the tops and while the amounts in the tops continued at a constant level. Potato plants can be developed in a series beginning with the small plants tuberizing very early, then larger plants tuberizing later but more extensively, then still larger plants tuberizing still later and less extensively or not at all, and finally considerably smaller plants that produce neither stolons nor tubers.

A Five-year Summary of Fertilizer Results on Irish Potatoes

By EARL F. BURK, *Oklahoma A. & M. College, Stillwater, Okla.*

FOR the past 5 years, fertilizer tests have been conducted with Bliss Triumph Irish potatoes on the college farm at Stillwater. The purpose of the tests is to determine the most profitable kind, and quantity of fertilizer to use. The results of fertilizer tests are so variable from year to year due to climatic conditions, that it is necessary to run such tests for an extended period of time to obtain an average that will be dependable.

While these tests have been under way only 5 years, the results have been sufficiently definite as far as certain phases of the test are concerned, to deduct tentative conclusions. The tests were conducted on a fine sandy loam soil, having a fine sand subsoil 12 to 24 inches beneath the surface. In the fertilizer mixtures used, nitrogen was derived one-half from nitrate of soda and one-half from sulfate of ammonia; phophorus, from 16 per cent superphosphate; and potash, from muriate of potash. There were three 1/50-acre plots for each treatment, and 15 no-treatment plots grown each year. The crops were planted each year about March 10, and harvested about June 20. The data for the 5 years are shown in Tables I and II.

The data show that 400 pounds of a 4–8–4 fertilizer increased the yield 42 bushels per acre over the unfertilized. When grown under

TABLE I—EFFECT OF DIFFERENT RATES OF APPLICATION OF A 4–8–4 FERTILIZER AND OF AN 800-POUND APPLICATION USING DIFFERENT PERCENTAGES OF NITROGEN

Fertilizer Pounds per Acre	Bushels per Acre	
	Ratio N-P-K	No. 1's and 2's
Rate Effect		
No fertilizer		75
400	4–8–4	117
600	4–8–4	120
800	4–8–4	120
1000	4–8–4	112
Nitrogen Effect		
800	0–8–4	108
800	2–8–4	123
800	4–8–4	120
800	6–8–4	120
800	8–8–4	124
800	10–8–4	113

TABLE II—EFFECT OF DIFFERENT PERCENTAGES OF PHOSPHORUS AND POTASH

Fertilizer Pounds per Acre	Bushels per Acre	
	Ratio N-P-K	No. 1's and 2's
Phosphorus Effect		
No fertilizer		75
800	4–0–4	83
800	4–4–4	114
800	4–6–4	124
800	4–8–4	120
800	4–10–4	123
800	4–12–4	122
Potash Effect		
800	4–8–0	117
800	4–8–2	120
800	4–8–4	120
800	4–8–6	110
800	4–8–8	114

conditions similar to those prevailing in this test, fertilization would, therefore, be profitable.

Phophorus increased the yield more than nitrogen or potash. A 6 per cent phosphorus content in an 800-pound application apparently was sufficient to supply the deficiency in the soil so far as the potato crop was concerned.

Small amounts of nitrogen and potash were beneficial, but the larger percentages of nitrogen caused reduced yields, especially in dry years. The average high yield obtained from an 8 per cent nitrogen application is due to the extra high yield of 1930, a season of high rainfall. Observations show that adequate rainfall during the month of May is essential to the production of high yields. In 1931–32–33 the May rainfall averaged 2 inches and the yield averaged 120 bushels per acre; while in 1930 the May rainfall was 6 inches and the yield 220 bushels per acre. On the whole, it appears that 400 pounds per acre of a 4–8–4 mixture was the most suitable fertilizer to use.

During 1 year of the test a crop of rye plowed under in February proved very detrimental to the yield of potatoes which followed the rye.

Relation of the Size of Seed Piece to Recovery of the Irish Potato After Killing of Tops by Cold

By L. M. Ware, *Experiment Station, Auburn, Ala.*

THE value of most experiments is increased as the number of years over which they have been conducted increases and as the seasons encountered include the normal variation of the section in which the results are to be applied. Some experiments, however, and especially certain phases of them, have a distinct value for a single year because of the peculiarities of that year. The season of 1932 furnished conditions which make the yield records on certain Irish potato plots for one year of special value and interest, especially as yields for the previous season permit certain quantitative comparisons of yield of potatoes from plants with injured and uninjured tops and with tops differing in size when injured by cold.

In 1931 a series of experiments was started at the Alabama Gulf Coast Substation to study the economics of production of Irish potatoes in the State's largest potato-growing section as affected by the interrelation of the three factors, namely, rate of fertilization, size of seed piece, and spacing. In March of 1932 the temperature dropped to 22 degrees F at the station while the plants in one experiment stood 5 to 6 inches and in another 8 to 10 inches in height. This temperature was low enough to cause complete killing of the shoots back to the ground and for two or more inches beneath the surface. This peculiar condition gave an unusual opportunity of determining the recuperative capacity of different sizes of seed pieces both independent of and as affected by the rate of fertilization and by the interval given in spacing. For purposes of comparison and of interpretation, yields for 1931 are given. Seasonal conditions in both 1931 and 1932, at the critical period of tuber development, were favorable for good production. There was no injury to the tops from cold in 1931.

The experiments were conducted on Norfolk sandy loam soil. Each plot was 1/60-acre in size and each treatment was triplicated. In each experiment there were 51 plots composed of three lines of 17 plots each. There were 15 check plots, every fourth plot in each line being a check. In the check plots 1500 pounds per acre of a 6–10–6 fertilizer, 1-ounce seed pieces, and 16-inch spacings were used. Using the data from the 15 check plots to determine the probable error of a single plot and adjusting this to the probable error of the triplicate plots used in deriving the average yields given in the tables for each treatment, then the probable error of each treatment expressed in percentage of the yield was 4.63 per cent in 1931, and 18.2 per cent in 1932 for the first experiment (Table I). For the second experiment the probable error of each treatment was 6.47 per cent of the yield in 1931 and 14.5 in 1932 (Table II).

In Table I is given the yield of marketable potatoes in 1931 and 1932 for three rates of fertilization and for four different sizes of seed pieces. The tops had reached a height of 8 to 10 inches at the time of the freeze in 1932. It should be noted that in 1931, when no killing

back of the tops occurred, good yields were produced even from ½-ounce seed pieces. In 1932, however, almost complete failure resulted from the use of ½- and ¾-ounce pieces, very low yields resulted from the use of 1-ounce pieces, and good yields were secured only when 1½-ounce or 2-ounce pieces were used. This means that satisfactory yields were produced from ½-ounce pieces where it was necessary for the tubers to supply food reserves for only one top but that the smaller seed pieces, including the ½-, the ¾-, and the 1-ounce pieces, were unable to supply sufficient food-reserves for the production of a second top capable in turn of producing a satisfactory yield. Pieces 1½ to 2 ounces in size appeared able, however, to furnish the food-reserves necessary to produce a second top, although considerable growth of the first top had been made before they were killed.

TABLE I—YIELD OF POTATOES FOR DIFFERENT RATES OF FERTILIZERS AND DIFFERENT SIZES OF SEED PIECE FOR TWO VERY DIFFERENT SEASONS:—1931, A NORMAL YEAR; 1932, TOPS KILLED BY COLD WHEN 9 INCHES HIGH

Pounds per Acre 6–10–6* Fertilizer	Yield of Marketable Potatoes for Different Sizes of Seed Piece (Bushel per A.)											
	½-oz		¾-oz.		1-oz.		1½ oz.		2-oz.		Average	
	1931	1932	1931	1932	1931	1932	1931	1932	1931	1932	1931	1932
1000..........	136	10	141	14	151	40	165	55	—	—	138	30
1500..........	146	24	168	30	179	58	217	107	202†	148†	177	55
2000..........	179	23	202	47	191	60	214	115	—	—	198	61
Average.....	154	19	170	30	174	53	198	92				

*All pieces spaced 16 inches.
†Not included in average.

The difference in productive capacity of different sizes of piece for the two years may be quantitatively expressed by the percentage increase in yield for each successive increase in size of piece for the two respective years. Using only the average yield for the three rates of fertilization, approximate increases in 1931 of only 10, 2, and 14 per cent were recorded as the pieces progressively increased in size from ½ to ¾ ounce, from ¾ to 1 ounce, and from 1 ounce to 1½ ounces, respectively. In 1932 the increases were 58, 77, and 73 per cent, respectively, for the same increases in size of seed piece. These greater percentage increases in yield in 1932 show in a very striking way the much greater importance of each increase in size of piece in years where a second top system must be produced from the food reserves of tubers, and the value of large pieces in such years.

Although increases in yield in both years were obtained for each increase in the rate of application of fertilizer and for each increase in size of seed piece with only two exceptions, yet the adequacy of the smaller pieces to produce good crops in years where no killing of the tops occurs stands out in strong contrast to the inadequacy of the smaller pieces to produce good crops where a second crop had to be produced. This may be shown by comparing the ratios of yield

of potatoes in 1931 to the yield in 1932 for each size of piece. This ratio at the 1500-pound-per-acre rate of fertilization was approximately for the ½-ounce piece, 6.1 to 1; for the ¾-ounce piece, 5.6 to 1; for the 1-ounce piece, 3.1 to 1; for the 1½-ounce piece, 1.9 to 1; and for the 2-ounce piece, 1.4 to 1. The 2-ounce piece in 1932, it will be seen, was able to produce a second top and a yield 73 per cent as large as that produced by the 2-ounce piece in 1931, while ½- and ¾-ounce pieces in 1932 after producing a second top were able to produce only about 17 and 18 per cent, respectively, of the crop produced by the same size pieces in 1931. While one cannot assume that the yield from plants with uninjured tops for the 2 years would have been the same for the same size of piece and for the same rate of fertilization, yet the above comparison is nevertheless valuable and interesting.

TABLE II—YIELD OF POTATOES FOR DIFFERENT SIZES OF SEED PIECE AND DIFFERENT SPACINGS FOR TWO VERY DIFFERENT SEASONS:—1931, A NORMAL YEAR; 1932, TOPS KILLED BY COLD WHEN 6 INCHES HIGH

Spacing in Inches*	Yield of Marketable Potatoes for Different Size of Seed Piece (Bus. per A.)									
	½-oz		1-oz.		1½-oz		2-oz		Average	
	1931	1932	1931	1932	1931	1932	1931	1932	1931	1932
8.......	196	46	238	110	201	157	—	—	212	104
12.......	151	50	195	102	205	153	—	—	184	101
16.......	142	58	193	105	227	165	—	—	187	109
20.......	185	68	205	133	223	169	237†	174†	212	123
24.......	—	—	—	—	—	—	—	—	—	—
Average..	168	55	208	113	214	161	—	—	204	—

*1500 pounds of a 6–10–6 fertilizer used.
†Not included in average.

The data presented in Table II are based on an entirely separate but related experiment occupying a different tier and started on a different date from the one just described. Plants in this experiment were, at the time of the freeze, only about 5 to 6 inches in height, and consequently had drawn on the tubers for less materials than had the plants in the first experiment. It will be noted that the recuperative capacity for each different size of piece, as indicated by the much greater yield from each larger seed piece, was greater in this experiment than in the first experiment. Thus, the yield for the ½-ounce and for the 1-ounce pieces in the potatoes less advanced at the time of the freeze was as great as for the 1-ounce and 1½-ounce pieces, respectively, in those more advanced. Unsatisfactory commercial yields were produced by the ½-, ¾-, and 1-ounce pieces from potatoes with the more advanced tops, while the 1-ounce pieces from potatoes with the less advanced top produced a yield approximately equivalent to the average commercial yield of the Gulf Coast section of Alabama. In this experiment the percentage increases in yield at the 20-inch spacing as the pieces progressively increased in size from ½ to 1 ounce, from 1 ounce to 1½ ounces, and from 1½ ounces to 2

ounces, for 1931 were 11, 9, and 7 per cent, respectively, and for 1932 were 95, 27, and 3 per cent respectively. The ratio of yield of potatoes in 1931 to the yield in 1932 for each size of piece at the 20-inch spacing was for the ½-ounce piece, 2.72 to 1; for the 1-ounce piece, 1.54 to 1; for the 1½-ounce piece, 1.32 to 1; and for the 2-ounce piece, 1.36 to 1.

It will be noted that the percentage increase in yield in this experiment for 1932 after the 1-ounce size piece was reached was very small compared to the increase in the first experiment, although the inadequacy of the ½-ounce piece even where the tops were not so advanced is very apparent. In 1932 at the 20-inch spacing an increase in yield of approximately 27 per cent was made by increasing the size of piece from 1 ounce to 1½ ounces, while only a 3 per cent increase was made by increasing the size of piece from 1½ to 2 ounces. This indicates that when the tops were killed at 5 to 6 inches height the 1-ounce piece was hardly large enough but that the 1½-ounce piece was amply large to develop a second top and produce as large a crop as the season permitted since an increase in size of seed piece from 1½ to 2 ounces gave no significant increase in yield.

It is interesting to note in both experiments where the tops were killed that the size of piece dominated the yield. Although the yield was affected by the rate of fertilizer and by spacing, especially by the former, the range of yields with a given size seed piece for all rates of fertilizer, excepting one, and for all spacings was narrow compared to the range of yields for different sizes of seed pieces.

The value of data which show the effect of cold damage on the yield of potatoes where different sizes of piece are used may be appreciated when the records in the potato growing area of the Gulf Coast section show that in the last 40 years there have been reported 28 killing frosts after February 10, 23 after February 20, 20 after March 1, and 13 after March 10. The damage in these years has varied from slight top injury to complete killing of the tops.

Storage Losses with Sound and Damaged Triumph Potatoes[1]

By H. O. WERNER, *University of Nebraska, Lincoln, Neb.*

CONTINUAL storage of sound tubers in a typical western potato cellar or cave has resulted in a greater loss of weight and more sprouting but less rotting than when cold storage (37 to 40 degrees F) was used. A short period of cold storage, from May 10 or 15 to June 10 or 20 was very effective in preventing both sprout growth and rot whereas cold storage from April 1 till June was almost as effective as continual cold storage in preventing weight loss and sprouting and more effective in preventing rotting. When tubers were removed from cold storage at different dates in the spring weight losses and sprouting decreased as cold storage was prolonged. Six weeks of cold storage in the fall was found to be the most unsatisfactory of all methods because of the high percentage of rot which developed.

When damaged potatoes were stored in the cellar, tubers cut in half lost most weight followed by those completely feathered and those from which a tangential slice had been cut, while bruised potatoes and those with cracks or cuts into the tubers lost least of all. Rotting of tubers was responsible for most of the difference in weight loss.

When the cut surfaces of tangentially cut potatoes were exposed to the sun for 1, 4, and 8 hours the loss of weight and rotting increased as did the length of the exposure. The loss was much less when cut surfaces were turned away from the sun. When cut tubers were held in a warm (60 degrees F) humid room for one week the losses were reduced very greatly.

If cut potatoes were taken into the cellar at once a very high and commercially satisfactory percentage could be preserved till June but losses were very great if held in cold storage either all of the time or for 7 days or for 6 months after harvest. The use of cold storage in the spring was satisfactory but not distinctly superior to continual cellar storage.

The major factor in preventing losses of weight and rotting was the healing of wounds. Because of that a period of warm storage for a short time after harvest was very desirable and cellar storage in the fall was superior to cold storage.

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Influence of Watering Treatment on the Occurrence of Blossom-end Rot in Greenhouse Tomatoes

By G. J. Stout[1], *Pennsylvania State College, State College, Pa.*

STUCKEY and Temple (1911) demonstrated that blossom-end rot of tomatoes was due to physiological rather than pathological causes and that it "can be prevented, if not entirely controlled, by keeping an abundant supply of water in the soil." The fact that soils in which tomatoes are growing may dry out slowly without causing any sign of the disease, has led to the belief that a water deficit following a prolonged period of abundant soil moisture is generally the cause of the disease. In some soils the disease has been increased by heavy manuring, although more recently recommendations have been made to increase the manurial application to greenhouse tomatoes, the theory being that the resultant increase in water-holding capacity of the soil will reduce the amount of blossom-end rot. Thompson (1927) has shown that pruning increases the amount of blossom-end rot on out-of-door tomatoes, because of reduced root development on tomato plants which have been pruned.

Greenhouse tomatoes are always pruned and the soils are always heavily manured. Also, greenhouse tomatoes are usually watered frequently enough so that the soil never becomes even slightly dry. This practice is based somewhat on the statement of Stuckey and Temple (1911) that in their experiments, "the more thoroughly the watering was done the less the rot." Observations have led to the conclusion that under the above conditions a serious water deficit occurred within the plant, as evidenced by decided wilting of the tops, due to the inability of the root system to absorb sufficient moisture from a soil which contained an adequate supply of water.

An experiment was begun to determine the influence of the time and amount of water applied on the behavior of the tomato roots and the occurrence of blossom-end rot. A greenhouse bed, 24 x 54 feet, was divided into 12 plots, each 9 x 12 feet, by sinking 1 x 12-inch boards into the soil edgewise, with about 2 inches of the upper edge above ground. This effectively prevented the water which was applied to one plot from flowing over into the next. Twenty-four plants of tomatoes of the Marhio variety were set in each plot on February 1, 1932. These were arranged in three rows of eight plants each; the rows were 3 feet apart and the plants 18 inches apart in the row. The individual plant records of the number, weight, and number of fruits with blossom-end rot were taken on the six plants in the middle row, one plant at each end of this middle row, and the two outside rows of each plot being considered as guards. A row of guard plants was also set around the outside of the experimental area.

Once each week, four soil samples were taken from each plot, one from the soil surface at each end, and one from a depth of 6 inches

[1]Experimental work conducted at Ohio State University under direction of Drs. J. H. Gourley and Richard Bradfield, of the Departments of Horticulture and Soils, respectively.

at each end of the plot. These were dried in an oven and the moisture percentages calculated.

A pipe in which small holes had been drilled was installed at a depth of 10 inches beneath the middle row of plants in plot A-4. Air from a small motor-driven pump was forced into this for a period of 30 minutes daily, to determine whether this amount of aeration would be beneficial.

All water applications were measured with a water meter reading to 0.1 gallon; a correction factor was applied to all readings to compensate for a slight inaccuracy in the meter. The watering treatments consisted of various combinations of two basic treatments. In one of these, water was applied lightly and at frequent intervals, always keeping the surface soil moist. This usually meant waterings every day in bright weather and less frequently when it was cool and cloudy. The other treatment consisted of heavy waterings at infrequent intervals, during which time the surface soil dried out considerably. The first irrigation was given immediately after the plants were set in the beds and no water was applied again for 4 weeks. In plots where this treatment was continued throughout the season, only 11 waterings were given in 6 months. Other plots (A-2, B-5, B-6) had light frequent waterings at first; later these received the heavy infrequent treatment, and one plot (A-3) was given the reverse of this treatment. The treatments and results are shown in Table I. The heavy-infrequent treatment is designated "H"; the light-frequent, "L"; and the watering treatments which were changed during the season are designated "L–H" and "H–L" respectively.

Plots A-1, A-4, A-6, B-2, and B-4, which were always given heavy infrequent waterings, produced much less blossom-end rot and many more pounds of sound fruit than did any of the adjoining plots which were given light-frequent watering at any period in their growth. The highest yield of sound fruit from any of the light-frequent treatments was from plot B-3, which produced nearly 27 pounds, or an average of 4.5 pounds per plant. The lowest yield of sound fruit on any of the heavy-infrequently watered plots was on B-2 with 40.5 pounds or an average of 6.75 pounds per plant, 50 per cent more than the best of the light-frequent treatments. The amounts of blossom-end rot fruits are in reverse order to these yields.

The light-frequent treatments generally produced the greater number of fruits, therefore the reduction in yield of sound fruits on these plants cannot be attributed to poor set of fruits. However, on A-2 and B-1, 75.5 per cent and 78.9 per cent respectively of the total number of fruits harvested were affected with blossom-end rot. The sound fruits produced on these two plots were of relatively small size. For example, the 78 sound fruits produced on the six plants in B-1 weighed 11.7 pounds or just slightly more than 2 ounces per fruit. In contrast, A-1 produced 170 fruits weighing 62.2 pounds or nearly 6 ounces each. All plots which were given heavy-infrequent waterings throughout the season produced sound fruits averaging over four ounces. Forcing air into the soil below the plants in plot A-4 gave no beneficial results as far as yield or number of blossom-end rot fruits was concerned.

TABLE I—SUMMARY OF TREATMENTS AND RESULTS SECURED WHEN GREENHOUSE TOMATOES WERE GIVEN VARIOUS WATERING TREATMENTS

Plot Number	Watering Treatments H=Heavy Infrequent L=Light Frequent	Average Amount Water Applied at Each Irrigation (Gals.)	Total Water Applied During the Season (Gals.)	Average Moisture Content Soil Surface, 23 Weekly Records	Average Moisture Content 6-inch depth, 23 Weekly Records	Total Number Fruits Harvested from Six Plants	Total Number Sound Fruits Harvested, Six Plants	Total Number B-end Rot Fruits from Six Plants	B-end Rot, Per cent of Total Number of Fruits Harvested	Weight Sound Fruits (Pounds, Six Plants)	Wt. B-end Rot Fruit (Pounds, Six Plants)	Per cent B-end Rot Fruit by Weight
A-1	11H	193.5	2027	25.2	26.8	203	170	33	16.2	62.2	5.2	7.8
A-2	{23L 7H	{19.7 170.5	1646	25.9	26.1	290	71	219	75.5	9.5	16.8	63.9
A-3	{3H 44L	{255.0 20.4	1663	27.3	27.1	262	154	108	41.2	30.8	10.4	25.3
A-4	11H	152.9	1682	27.4	27.4	218	171	47	21.6	48.9	5.4	10.0
A-5	59L	21.3	1257	28.9	28.1	225	103	122	54.2	22.3	16.6	42.8
A-6	11H	199.0	2189	25.6	27.0	243	202	41	16.9	53.5	4.9	8.4
B-1	59L	18.3	1079	23.9	25.1	370	78	292	78.9	11.7	21.6	64.8
B-2	11H	180.4	1984	26.3	25.7	239	166	73	30.5	40.5	11.4	22.0
B-3	59L	19.0	1122	27.7	27.4	283	116	167	59.0	26.8	15.0	35.8
B-4	11H	172.7	1900	26.9	27.1	234	192	42	17.9	51.3	5.3	9.4
B-5	{17L 7H	{16.2 170.4	1468	25.3	26.7	246	166	86	34.9	34.3	11.1	24.4
B-6	{23L 7H	{18.0 198.7	1805	25.9	25.9	313	118	195	62.3	23.0	16.4	41.7

The results indicate that proper watering is most important early in the life of the plant. This is shown by a comparison of the yields on plots A-2 and B-6 (L–H treatment) with plot A-3 (H–L treatment). Plot B-5 (L–H treatment) was superior to A-3 but was not strictly comparable to plots A-2 and B-6 because the light-frequent waterings were discontinued three weeks earlier on B-5 and the heavy-infrequent waterings were begun simultaneously with plots A-2 and B-6. During these 3 weeks the soil in B-5 dried out considerably but this drying appears not to have been harmful and was probably beneficial as measured by yield of sound fruits and freedom from rot.

Under the conditions of this experiment, none of the watering treatments was ideal, for there was some blossom-end rot in all plots. The ideal treatment probably lies somewhere between the two extremes employed in these trials.

No single explanation, adequate to account for these results, is to be found in the literature on blossom-end rot of tomatoes. The roots of many of the plants in all plots were excavated and studied. Some differences in breadth and extent were noted; the heavy-infrequent treatments tended to cause deeper and somewhat more extensive rooting. The most striking effect, however, was the large number of fine rootlets which had been produced at depths of 3 to 15 inches in all plots but which were practically all dead in the plots which had been given the light-frequent waterings. These fine rootlets were still alive and healthy in the heavy-infrequently watered plots. This suggests that some condition developed in the soil of the light-frequent treatments which was unfavorable to the existence of these rootlets. Poor soil aeration seems the most probable cause. In heavily manured greenhouse soils, especially those which have been steam sterilized immediately before planting the crop, the decomposition of organic matter and the evolution of carbon dioxide proceed very rapidly after the soil is steamed. A constantly moist surface soil greatly retards gaseous exchange between the subsoil and the atmosphere because the porosity of the wet surface soil is low and diffusion is greatly retarded in consequence. Under such circumstances, plants may suffer from water deficiency, because of poor soil aeration, even though the soil at a depth of 6 inches or more contains sufficient moisture for good crop growth.

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A Study of Some Factors Associated with the Occurrence of Cracks in the Tomato Fruit

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ALTHOUGH there have been no experimental studies made to explain the occurrence of cracks in the tomato fruit, the importance of the problem is well recognized. Space does not permit a presentation of data which have been collected in detailed studies on the problem during the past four years. Because of the dearth of knowledge on the subject it is felt advisable to summarize, briefly, certain conclusions which have been reached, with the idea that they may be of value to those who are now or may, in the future, be working on the problem.

MATERIALS AND METHODS

Crops grown and method of recording field data:—Greenhouse crops were grown in the fall of 1931 and 1932, to determine the effect of different water applications on the occurrence of cracks. A field crop was grown in 1932 to further study the effect of irrigation. In 1934, studies on the field crop included the effect of shading the entire plant with muslin; of bagging the fruits with cellophane or muslin; and a comparison of staked, pruned plants with non-staked, non-pruned ones.

In order to determine chronological age, and furnish a means of identification of individual fruits on the vine, flowers were tagged the day that they opened. The following data have been obtained on approximately 8,000 tagged fruits that attained the pink or later stages of ripeness: (1) Position of the cluster on the plant (with exception of field grown fruits in 1932, which were not staked), (2) position of the fruit on the cluster, (3) time of tagging, (4) day the fruit turned pink (reference point for physiological age), (5) day the fruit turned red-ripe, (6) day that cracking occurred, (7) degree of cracking (number and size, as well as position of cracks) when cracking first occurred, and (8) degree of cracking at time of harvest.

Laboratory studies:—An inquiry into the *causes* of noted differences in cracking between varieties and experimental treatments has been attempted. This part of the work has included studies of: (1) Chemical composition, (2) freezing point depressions, (3) H-ion concentration, (4) pressure tests, (5) absorption of water by immersed fruits, (6) intake of dye solutions, (7) temperature effects, and (8) anatomical studies.

RESULTS

Varietal susceptibility to cracking:—In 1931, data were taken on the cracking of Gulf State Market, Stone, Greater Baltimore, Early Detroit, Globe, Bonny Best, Marglobe, and Santa Clara Canner varieties under field conditions. With the exception of Gulf State Market, which showed appreciably less cracking, there is little difference in susceptibility among the varieties. Globe is almost iden-

tical in vine and fruit appearance to Gulf State Market, yet it is decidedly more susceptible to cracking. It was because of their apparent similarity that they were chosen for subsequent detailed studies, since obvious differences in varietal characteristics, with their possible relation to cracking, were thereby eliminated. A comparison of Marglobe, Greater Baltimore, Tri-State Baltimore, Pritchard, Stone, Brown's Special, Market Champion, and White's No. 4, in 1934, showed no outstanding differences in cracking.

Types of cracking and region of fruit most susceptible to cracking:—Tomato fruits may crack radially or concentrically. The former is more common, particularly under greenhouse conditions. Most of the cracks in tomato fruits, whether radial or concentric, appear at the stem end. Practically all of the radial cracks are connected with the corky layer of the stem end. Cracks radiating from the stem end are located mostly along creases which lie above or along the septae or interlocular walls. Concentric cracking of the "netted" type on the stem end is less likely to occur in red-ripe fruits than in green ones. Concentric cracking has been most prevalent late in the season in the two field crops grown in these experiments. It was severe only during a rainy period which was preceded by drought.

Effect of irrigation and rainfall:—Heavy irrigation throughout the season induced more cracking than occurred in plots left continually dry. However, dry treatment, followed by continued heavy irrigation, produced significantly more cracked fruits and larger cracking indices than heavy irrigation throughout the season. An increase in cracking was noted within 3 to 6 days after applying water to the soil of the dry series.

Rain is effective in producing cracking within a few hours. The water is absorbed through the corky layer of the stem end, or may be taken in through small corky areas in the skin. Perceptible increases in cracking following very light showers indicates that appreciable absorption of external water by the fruit is not necessary for cracking to occur, but that the mere decrease in transpiration of water from the fruit is apparently sufficient to cause expansion and subsequent rupture. Traces of water on fruit surfaces, particularly about the stem, are also probably a factor under these specific conditions. Severe radial cracking, especially, may occur during dry periods.

Effect of stage of maturity of fruit on percentage cracking and cracking indices:—The older the fruit becomes, the greater is the probability that it will crack. This tendency is especially pronounced up to the time the fruits reach red-ripeness. The longer a fruit is allowed to remain on the vine, especially after it reaches the mature green stage, the greater is the possibility that if it does crack, the cracking will be severe. Many radial cracks originate as very small ruptures emanating from the corky ring, and increase in size from day to day. Marglobe is particularly susceptible to this type of cracking.

Effect of position of fruit on cluster on cracking:—Of fruits of the same physiological age but borne in different clusters and plants,

those nearer the base of the cluster crack in the shorter time. This has been shown both in greenhouse and field studies. In individual clusters there are often exceptions, of course, to this behavior. It is a matter of common knowledge that the first fruits on the cluster are the larger ones. A size factor thus enters. Observations show, however, that size of fruit, within a variety, is not of major importance in cracking. The tendency for those fruits nearest the main stem to crack earlier is probably in some way associated with nearness to water and nutrient supply, rather than size, which is an accompanying factor.

Effect of shading the plant, and of bagging fruits with cellophane and muslin:—By shading the entire plant with muslin, severity of cracking has been reduced. Fruits from shaded vines are high in water content, low in freezing point depression, low in total sugars, free reducing substances, and total carbohydrates. Bags of colorless cellophane, green cellophane, muslin, and muslin plus cellophane (colorless cellophane inside a muslin bag) when placed over fruits about ½ inch in diameter and left until maturity reduced the amount of cracking as measured at the pink stage. Colorless and green cellophane were most effective in reducing cracking. No appreciable difference, however, in water content or the above chemical constituents was shown between fruits from the various bags or unbagged fruits.

Comparison of cracking of fruits from pruned, staked plants, and non-pruned, non-staked plants:—Results of one season's work show fruits from pruned, staked plants to crack more severely. Concentric cracking is particularly more prevalent on fruits from pruned, staked plants. It is generally supposed that, because of the small root system characteristic of pruned plants, they may suffer more from water deficit in times of drought. In these experiments it has been relatively easy to show a difference in water content of the fruit as influenced by high or low applications of water to the soil. No such differences, either in water content or carbohydrate constituents, have so far been shown in fruits from pruned as compared to non-pruned plants.

Chemical and Biophysical Studies

Water content of fruit:—Is the stem end, where cracking is most frequent, high in water? Numerous determinations on the ovary wall tissue have shown that it is higher in moisture than the stylar end. Since this is the fruit portion in nearest proximity to the stem, it is not surprising that the tissue should be higher in water content; consequently, the role which relatively high water may play in the cracking of the fruit in the stem end area becomes a matter of speculation. Within a given treatment water content of cracked and non-cracked fruits is similar. Merely the presence of high or low water does not mean that the fruit will or will not crack. Rather, it may be said that fruits low in water content are the ones most susceptible to severe cracking when conditions become favorable.

It has been shown by freezing point depression measurements that fruits on vines given a low water supply, than plentifully supplied

with water, can not be expected to become relatively high in water content of ovary wall tissue within the course of a few days. Yet cracking will have increased appreciably.

Carbohydrate and pectic constituents:—Protopectin is higher in ovary wall stem end tissue than in the stylar end when the fruit begins to ripen. In spite of this fact, cracking normally occurs at the stem end. It would seem, nevertheless, that the breakdown of protopectin, a cementing substance, accompanying maturity may be one of the reasons for the larger cracking indices of red-ripe fruits.

The Globe variety, which cracks the more badly, is slightly higher in total and reducing sugars than Gulf State Market. The differences appear too small to be of great importance, however. Although shaded vines produce fruits with low total carbohydrate content, it must not be concluded that this is the causal factor for their low cracking indices. The direct effect of sun on cutin, difference in temperature, and partial shedding of rain by the muslin, are other factors which may enter in.

Hydrogen-ion concentration:—Highest hydrogen-ion concentration occurs in fruits just as they begin to turn pink. At this stage of maturity the hydrogen-ion concentration of stem end ovary wall tissue is consistently lower than that of the flower end ovary wall tissue. It is conceivable that this gradient in pH, with its effect on swelling of bio-colloids, may have some connection with cracking. It results probably from a difference in ripening rate of the two ends of the tomato fruit, for the flower end usually turns pink first. Since no such gradient is present in red-ripe fruits and so can not be a factor in cracking, there is doubt as to its value in promoting cracking of mature green or pink ones. No difference in the pH of cracked and non-cracked fruits of the same age has been found, nor has water treatment produced fruits differing in pH. The conclusion seems justified that hydrogen-ion concentration of the ovary wall tissue is not of importance in cracking of tomato fruits.

Puncture tests:—Since it was found that most of the radial cracks occur in the creases of the fruit, it was desirable to find whether the resistance to puncture in this area might be less than on other portions of the fruit. A common corn pressure tester, with a piston .514 mm in diameter was used. In every case tremendous odds have been obtained showing that the resistance of the crease to puncture is much less than that of regions between the creases or at the flower end. Care was taken to hold the pressure tester at an angle, that provided flat contact of the piston and skin at the bottom of the crease. Underlying tissue, as well as skin, combines to offer resistance to the pressure. This should not be considered objectionable because the tissues beneath the skin must certainly play some part, as well as the skin itself, in resistance to cracking. Specimens imbedded in paraffin, and sectioned across the fruit creases near the stem end and parallel with the central core of the fruit, when stained with Sudan III and Delafield's Haematoxylin, show a fission of the tissue lying directly beneath the crease. Microscopic examination shows the cleavage region to be often present, although visible cracking of the fruit skin has not occurred.

When fruits are immersed in solutions of methylene blue, the stain is absorbed by the corky area of the stem end in many cases and diffuses mainly along the creases or septae. Such fruits, after remaining in the solution for a few hours, then allowed to dry, present a distinct pointed pattern radiating from the stem end. Absorption of water in this area during rainy periods without doubt aids in producing cracking. It was found that fruits with smooth skins, and with the corky layer paraffined, would not absorb water.

"Corky" spots appear on the shoulders of many fruits. Stain is absorbed by these small areas, and often can be seen diffused into the tissue immediately beneath. Such spots are capable of absorbing moisture and thereby encourage cracking.

Summary

Of the factors and conditions studied with relation to cracking, it appears that the following are intimately associated with the phenomenon: Absorption of external moisture by corky spots or the corky layer of the stem end, age of fruit, position of the fruit on the cluster, presence of fission areas in the tissue lying beneath the creases, bagging of fruits with muslin or cellophane, shading the plant, and change from low to high soil moisture. Those factors of minor importance are: Hydrogen-ion concentration, actual water content of the fruit, chemical composition, and size of fruit.

It is not possible to say just how the listed apparently correlated factors *immediately* affect the cracking of tomato fruits. Indeed, it still remains to be positively proved that *most* of them are truly correlated with cracking, and not chance parallel occurrences. The most perfectly consistent effect has been the cracking following applications of water to the fruits or to the soil.

Effect of Irrigation, Degree of Maturity, and Shading Upon the Yield and Degree of Cracking of Tomatoes

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ONE hundred tomato plants of the Prichard variety were selected in a block of five rows of 20 plants each from the regular University planting for these tests. The plants were planted 4 by 4 feet and were staked but not irrigated. They were unpruned and were tied with twine around individual 1½x1½-inch stakes, 5 feet high. Each plant was tagged so that plants from which green fruits were harvested alternated in all four directions with plants from which ripe fruits were harvested.

All fruits were harvested regardless of size when they reached the desired degree of color. The first fruits were harvested July 17 and at 3-day intervals thereafter until September 21. Aside from a mild infestation of white fly and mosaic no other disease or insect pest was present to any noticeable degree. One plant (in the plot from which ripe fruits were picked) died near the end of the tests.

Results

At the end of the twenty-third picking the total yields for each plot of 50 plants were as shown in Table I. The yields seem to indicate a slight advantage in both weight and numbers for the green picked fruits. When one considers the fact that the ripening process takes several days more, this difference loses its significance.

TABLE I—Total Yields Showing Effect of Degree of Maturity on Yields of Tomatoes

Treatment	Number of Fruits per Plot (50 Plants)	Wt. Fruits (50 Plants)	Pounds per Acre	Ave. Wt. Fruits (Pounds)
Picked green	2527	475.9	25,699	.188
Picked ripe	2302	459.4	24,808	.199

At the twenty-third or last picking there was a difference in yield of 16.5 pounds in favor of the green picked fruits. Since the average picking of ripe fruits amounted to approximately 20 pounds per plot it is reasonable to assume that there were at least 16.5 pounds of unpicked fruits on this plot that were ripe enough to be picked in the green stage as described in this paper. If this is true the yields of the two plots would have been identical.

The yields at the end of the eleventh picking are shown in Table II. There was at that time a difference of 350 fruits with a weight of 46.0 pounds in favor of the green picked fruits. It is obvious that a grower would have reaped a considerable financial gain by picking green fruits if the price had declined at this time. From that picking to the end of the project this lead of 45 per cent in weight in favor of green picked fruits was rapidly decreased until at the twenty-third picking the lead was only 3.5 per cent.

TABLE II—YIELD AT END OF ELEVENTH PICKING

Treatment	Number of Fruits per Plot (50 Plants)	Wt. Fruits (50 Plants)	Pounds per acre	Ave. Wt. Fruits (Pounds)
Picked green	780	137.1	7,403	.176
Picked ripe	430	91.1	4,919	.212

At the eleventh picking the average weight per fruit of the green picked fruit was only .176 pounds while that of the ripe fruits was .212 pounds. The average weights of all fruits picked for the entire project was .188 pounds for green picked fruit and .199 pounds for ripe picked fruits. As stated before all fruits were picked regardless of size, hence the total weights and the average weight per fruit would not coincide with the results of regular commercial practices. In that case the number picked would be less and the average weight per fruit higher.

In conclusion, it is evident that aside from the early yields, the total or final weights of tomatoes picked from these plots were approximately the same regardless of the stage of maturity at which they were picked. It is also concluded that by picking green, nearly mature tomatoes, a greater weight of fruit can be harvested at an earlier date than can be gathered if the fruits are allowed to ripen on the vines. This latter point is usually important when tomatoes are grown for the early market as market prices are usually higher early in the season. Farmers who grow tomatoes for canning can allow the fruits to ripen on the vines with considerable assurance that the yield will not be reduced as a result, although it would no doubt be advisable to keep all ripe fruits picked near the end of the season to avoid losses from frosts.

STUDIES IN THE CONTROL OF TOMATO FRUIT CRACKING

Field tomatoes are frequently marred by radial cracking of the skin and flesh at the stem end of the fruit. Often horizontal (or circular) cracks appear either with or without radial cracks. Many attempts have been made to explain the presence of these cracks. It is known that they are not present under glass when proper forcing environments prevail. Some growers claim that field-grown fruits that are shaded by the leaves crack less than do unshaded ones. This led to the thought that shading the entire plant might give the desired control. It was the purpose of this project to test this idea.

The radial cracking varies considerably in its severity both from year to year and with the individual fruits during the year. For the purpose of this investigation, typical examples of the several degrees of cracking were chosen and labelled numbers 1 to 5 respectively. These grades are defined as: (1) Free from cracks, (2) slight cracking, (3) moderate cracking, (4) severe cracking, and (5) very severe cracking. Both radial and circular cracking were considered in placing the tomatoes in their respective grades.

Immediately adjacent to the east of the plants used for first part of this project five rows of four plants each were selected in a block. The rows were numbered 1 to 5 from south to north. A three-sided covered cheesecloth shelter was erected entirely over rows 1 and 2 with the open side to the north. There were two rows of four plants each under this shelter. Row 3 was used as a separator row to assure that there would be no shade thrown on rows 4 and 5. The tomatoes in row 3 were not picked. This arrangement gave two rows of a total of eight plants under shade, and a like set of two rows (eight plants) unshaded. One-half gallon of water was applied daily to each of four shaded plants and to each of four unshaded plants. A circular mound of earth was built up around the base of each plant to confine the water as it was applied.

In order to give the fruits ample opportunity to crack, they were allowed to remain on the vines until they were dead ripe, i.e., about 3 days after they became fully ripe. At first pickings were made at 9-day intervals, but later as the fruit ripened more rapidly this was reduced to 6 days.

In addition to the 16 special plants, all of the fruits harvested from the 100 plants used in the fruit test were graded to show the differences in degree of cracking. The arrangement then gave three tests: (1) The effect of shade on the degree of cracking, (2) the effect of water on the degree of cracking, and (3) the difference in the degree of cracking of fruits, picked from unshaded and unwatered plants, at two stages of maturity, i.e., just turning and fully ripe.

Watering was started 6 days before the first fruits were harvested, and continued throughout the test. The first fruits were picked July 23. Three pickings were made at the 9-day interval and seven at the 6-day interval. This gave a total of 10 pickings with the last on September 21. Though a quantity of fruit remained on the vines, they were disregarded when the tests were concluded. One plant in the shaded but not watered plot died on September 15. All of the other plants were about half dead at the end of the project.

TABLE III—Number and Weight of Fruits Picked From Shaded and Irrigated Plants

Grades	Not Shaded (Check)		Not Shaded Plus ½ Gal. Water Daily		Shaded		Shaded Plus ½ Gal. Water Daily	
	No.	Wt.	No.	Wt. (Pounds)	No.	Wt. (Pounds)	No.	Wt. (Pounds)
1	95	16.1	86	15.2	117	18.2	91	16.3
2	46	9.1	58	12.3	35	7.5	47	9.5
3	32	7.0	24	5.6	12	5.9	22	4.4
4	11	2.2	14	3.6	—	—	14	3.2
5	2	.3	8	2.1	3	.6	3	.5
Totals...	186	34.7	190	38.8	167	32.2	167	33.9

Table III gives a summary of the number and weight of fruits picked from all plots and their grading. These results are expressed in percentages in Table IV.

TABLE IV—DEGREE OF CRACKING IN PERCENTAGE OF TOMATO FRUITS HARVESTED FROM SHADED IRRIGATED PLOTS

Grades	Not Shaded (Check)		Not Shaded Plus ½ Gal. Water Daily		Shaded		Shaded Plus ½ Gal. Water Daily	
	No.	Wt.	No.	Wt. (Pounds)	No.	Wt. (Pounds)	No.	Wt. (Pounds)
1	51.08	46.53	45.26	39.24	70.06	56.39	51.41	48.03
2	24.73	26.10	30.53	31.75	20.96	23.13	26.55	28.07
3	17.20	20.16	12.63	14.50	7.19	18.48	12.43	13.07
4	5.91	6.01	7.37	9.19	—	—	7.91	9.29
5	1.08	1.08	4.22	4.22	1.79	1.79	1.13	1.13

Tables V and VI summarize the degree of cracking for the fruits on the shaded and irrigated plots in per cent.

TABLE V—DEGREE OF CRACKING FROM SHADED AND UNSHADED TOMATO FRUITS (PER CENT)

Grades	Not Shaded—Not Shaded Watered		Shaded—Shaded Watered	
	No.	Wt.	No.	Wt.
1	48.14	42.88	60.46	52.21
2	27.66	29.92	23.84	25.60
3	14.89	17.33	9.88	15.18
4	6.65	7.60	4.07	4.64
5	2.66	3.11	1.74	1.75

TABLE VI—DEGREE OF CRACKING OF FRUITS GROWN ON WATERED AND NOT WATERED PLANTS (PER CENT)

Grades	Not Shaded—Shaded		Not Shaded Watered—Shaded Watered	
	No.	Wt.	No.	Wt.
1	60.06	51.46	48.23	43.63
2	22.95	24.61	28.61	29.91
3	12.47	19.32	12.53	13.77
4	3.12	3.00	7.63	9.24
5	1.42	1.42	3.00	3.44

It can be seen that beyond a doubt shading is beneficial in reducing the severity of cracking. This benefit amounts to a 10 per cent increase in No. 1 fruits and a proportionate reduction in all other grades in favor of higher grades.

It can be seen from these tables that water increases the degree of cracking. The difference is due mostly to an increase in the weight of fruit in grades 4 and 5 and a corresponding decrease in No. 1 fruits from the watered plots. Table VII gives a resume of the numbers and weights with the percentages of the fruits picked green and ripe.

It can be seen from this table that there is a 15 per cent decrease in No. 1 tomatoes when the tomatoes are allowed to ripen on the vine as

compared to the green picked tomatoes. It is reasonably correct to say that the greener the fruit is picked the less the degree of cracking. Conversely as ripening increases the degree of cracking increases.

TABLE VII—DEGREE OF CRACKING OF GREEN AND RIPE TOMATO FRUITS GROWN ON UNSHADED PLANTS

Grade	Green Fruits			
	Number		Weight	
	No.	(Per cent)	(Pounds)	(Per cent)
Free of cracks	1512	59.83	266.4	55.98
Slight cracking	782	30.90	135.2	32.59
Moderate cracking	177	7.00	40.1	8.44
Severe cracking	45	1.78	12.1	2.55
Very severe cracking	11	.44	2.1	.45
Grade	Ripe Fruits			
	Number		Weight	
	No.	(Per cent)	(Pounds)	(Per cent)
Free of cracks	1098	47.69	188.8	41.08
Slight cracking	779	33.84	170.1	37.03
Moderate cracking	261	11.34	60.1	13.11
Severe cracking	127	5.52	32.2	7.01
Very severe cracking	36	1.56	8.2	1.78

CONCLUSIONS

(1) Shading the entire plant reduces the severity of cracking. It does not eliminate it. (2) Water as applied increases the severity of cracking. (3) The degree of cracking increases with the stage of ripeness at which the fruit is picked. At none but the very immature stages are all of the fruits entirely free from cracks.

The Variation in Temperature of Tomatoes and their Color Development

By JOHN H. MACGILLIVRAY, *Purdue University, Lafayette, Ind.*

DUGGAR (1), Rosa (3), and Harvey (2) have called attention to the relation of high constant temperatures to the production of yellow pigment (carotin) and the suppression of the red pigment (lycopin) development in tomatoes. This paper reports temperature readings of field grown tomatoes, and shows that high temperatures during a portion of the day did not entirely supress red pigment development. The above workers found when tomatoes of a whitish green color of normally red varieties were placed in ovens at a temperature of greater than 30 degrees C, the fruit developed little of the red pigment lycopin, but were yellow due to the presence of carotin. Although temperature seems the important factor affecting color, there may be certain growth conditions, such as the amount of foliage, which will affect the temperature of the fruit and consequently its color.

The temperature of tomato fruits was obtained by means of thermocouple wires and a galvanometer which permitted the recording of temperatures within 0.29 degrees F. The thermocouple wires were pushed into the flesh of the tomato for about one-half inch. The air temperatures given in the tables were obtained from a Government Station ¼ mile from the tomato field.

The temperature of a tomato fruit seems to vary directly with air temperature. The side of the fruit nearest the sun is higher in temperature than the shaded side. Fruits which are well protected by leaves may be anywhere from 13 to 25 degrees lower in temperature at noon than fruits exposed to the direct rays of the sun. Fruits with poor foliage protection have the greatest daily range in temperature, because they are warmer at noon and slightly cooler at night. In the tomatoes described in Table I, there were the following ranges in temperature: Poor foliage, exposed side (No. 4) variation 47.1 degrees F, shaded side variation 26.1 degrees; good foliage, exposed

TABLE I—DAILY VARIATION IN THE TEMPERATURE (DEGREES F) OF TOMATOES WITH GOOD AND POOR FOLIAGE PROTECTION (1932). INDIANA BALTIMORE VARIETY

Temperature of Air Government Station		DATE	Poor Exposed 1	Poor Shaded 1	Poor Exposed 4	Poor Shaded 4	Good Exposed 8	Good Shaded 8
7/19–20	9/16–17		7/19–20	7/19–20	9/16–17	9/16–17	9/16–17	9/16–17
98	76	Noon.....	113.9	104.7	87.3	75.7	68.5	66.6
98	75	2:00 p.m...	——	——	93.9	77.7	69.4	67.5
97	74	4:00 p.m...	100.0	100.0	84.6	76.6	67.3	63.9
85	63	8:00 p.m...	85.6	86.5	56.5	60.3	58.3	57.9
77	55	Midnight	76.6	75.4	46.8	49.6	52.0	52.2
90	58	8:00 a.m...	90.3	89.2	52.9	49.6	50.4	52.0
96	69	10:00 a.m..	——	——	77.4	63.3	60.3	57.4
102	76	Noon.....	117.7	104.5	86.9	73.2	68.7	65.8

side (No. 8) variation 19.0 degrees, and shaded side variation 15.5 degrees. Table II gives the following variations in temperature: Poor foliage (9/7/1933) 38.6 degrees, good foliage 23.2 degrees; and poor foliage (9/29/1933) 32.6 degrees, good foliage 15.5 degrees F. The temperature of a fruit with scant foliage was 24.5 degrees F higher than a similar fruit with good foliage. Rosa (3) pointed out that the ripening temperature not only affects the final color but also the speed of ripening, consequently the poor foliage fruits would be expected to ripen more rapidly since they are subjected to a higher temperature during the day, but slightly lower temperatures at night.

Duggar, Rosa, and Harvey performed their experiments where the temperature was uniform throughout the day, while field tomatoes are subjected to variation in temperature. Such experimental data could be most beneficially applied to the ripening of "green wrap" tomatoes in the terminal markets. It has also been considered in connection with vine ripening fruits because there was no better information available. Rosa states a temperature of 23 to 25 degrees C (73–77 degrees F) is most desirable for lycopin development with little lycopin development above 30 degrees C. Duggar and Harvey found no development of red color at 32 degrees C and above. Field ripened tomatoes may have a portion of the stem end yellow in color, but it is uncommon to find as much as 25 per cent yellow and never the whole fruit. From the data in Tables I and II, it is not uncommon for fruits to have temperatures of 90 degrees F or more, but never for 24 hours at one time. Most fruits whose temperature was above 90 degrees F a portion of the 24 hours would pass as U. S. No. 1's in color. High temperatures must surely be undesirable for color development in vine ripened fruits, but it seems likely that the lower temperatures at night may permit lycopin development during a greater part of the 24 hours.

TABLE II—Relation of Amount of Foliage and Time of Day to the Temperature (Degrees F) of Tomato Fruits (1932–33). Temperature Obtained Midway Between Part Exposed and Shaded from the Sun. Indiana Baltimore Variety

	Date	Number of Fruits	8 a.m.	Noon	4 p.m.	8 p.m.	Midnight
Poor foliage	9/8/32	10	—	100.1	—	—	—
Medium foliage		10	—	81.0	—	—	—
Good foliage		7	—	74.6	—	—	—
Air temperature (Degrees F)				73			
Poor foliage	9/7/33	7	71.6	106.2	99.7	77.5	67.6
Medium foliage		7	73.4	95.5	91.6	77.4	69.4
Good foliage		7	73.2	93.4	88.5	78.1	70.2
Air temperature (Degrees F)			80	93	93	82	75
Poor foliage	9/29/33	9	58.5	84.2	75.6	57.4	51.6
Medium foliage		7	58.1	70.3	69.1	59.0	53.6
Good foliage		7	57.7	65.7	70.5	59.7	55.0
Air temperature (Degrees F)			56	70	74	65	60

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Artificial Light as an Aid to Tomato Grading

By F. C. Gaylord and John H. MacGillivray, *Purdue University, Lafayette, Ind.*

IN establishing the grade on a load of tomatoes, the color of the tomatoes is a very important factor. The light which falls on these fruits makes a difference in their color. Natural daylight has been most frequently used, but this is variable in quality. When one considers that the color of an opaque object such as a tomato depends upon the absorption characteristics of the fruit; the quality of light falling upon the fruit; and the color sensitivity of the eyes of the observer, it is evident that the last two conditions must be controlled as accurately as possible.

Quality of light or color temperature is expressed in degrees Kelvin. A light of about 5300 degrees K is considered to be a neutral white light or practically noon sunlight, higher color temperatures become more and more bluish, while lower temperatures are progressively more yellowish. The following definitions of color temperature and degrees Kelvin are of interest in discussing quality of light: "It has been found by experiment that the light from most, but not all, ordinary illuminants can be matched in color by the light from a black body operating at some particular temperature which is called the color temperature of the source in question" (4). "The (color) temperature is measured on the absolute work scale (degrees Kelvin) and is approximately degrees centigrade plus 273" (3).

According to Priest, (5) the color temperature of sunlight usually is 1900 degrees K at 17 minutes after sunrise or before sunset, 2500 degrees K at 33 minutes after sunrise or before sunset, 3500 degrees K at 63 minutes after sunrise or before sunset, 4000 degrees K at 95 minutes after sunrise or before sunset, 4400 degrees K at 2 hours after sunrise or before sunset, and 5300 degrees K as average noon sun. Where direct sunlight is excluded and the light is reflected from a blue sky the color temperature may be from 7000 to 10,000 degrees K. Artists and technical color workers usually prefer the light from a north window when the sky is blue. This type of light is variable, but it is usually whitish blue with a color temperature of about 6000–6500 degrees K. Most artificial light is below 5400 degrees K, or is a yellowish white. The color temperatures of the following light sources will give some idea of their variation: Candle (paraffin), 1920 degrees K (6); kerosene lamp (flat wick), 2045 degrees K; tungsten-filament, gas-filled bulbs, 40-watt, 2710 degrees K (1), 75-watt, 2805 degrees K, 100-watt, 2840 degrees K, 150-watt, 2850 degrees K; 200-watt, 2870 degrees K; blue daylight lamp bulb, there is little information on individual sizes but the average temperature is approximately of 3600 degrees K. Voltage, also, has some effect on color temperature, as a 100-watt lamp has a color temperature of 2732 degrees K at 105 volts, 2779 degrees K at 110 volts, 2825 degrees K at 115 volts, and 2914 degrees K at 125 volts (2). In order to obtain lamps of a desired color temperature of 5500–6000 degrees K, it is necessary to use an ordinary electric light bulb and a glass

filter. The make of lamp as well as the wattage must be considered in the selection of the proper glass. Work was performed with such lamps which were sold by the General Electric Supply Corporation of Bridgeport, Connecticut, and are listed under the name of "Noon Sunlight Color Quality", and "North Skylight Color Quality". Similar lamps were used which were sold by the Macbeth Daylighting Company of New York City, who sell them under the names of "Whiterlite", and "Daylight" lamps. Both companies produce lamps that correspond to white light (about 5400 degrees K) and a whitish blue light (about 6300 degrees K). The latter company furnishes lamps to the purchaser on a definite color temperature basis, or graded for color temperature. The use of a glass filter in front of the bulb materially decreases the amount of light as compared to the bulb without the filter.

It can be seen from the data of Priest that daylight is variable in quality of light, and likely only 4 to 6 hours in the middle of the day are satisfactory for grading. Daylight is unsatisfactory for grading at least 2 to 3 hours each day, and during the peak production it may be as much as 6 to 7 hours, representing the receipts of 30 to 100 tons per day. Occasionally graders may work in three shifts per day when there would be a need of using artificial light for 16 hours. It is possible that it may be found desirable to use artificial light for tomatoes during the middle of the day, because of its uniformity of light quality.

Tomato graders commonly use frosted bulb lamps, frequently of insufficient wattage, which give a yellowish white light. In trying to improve the conditions for grading after sundown or at other times of inadequate light, following comparative studies were made with frosted bulb lamps, blue daylight bulbs, and the previously mentioned lamps with corrective filters. Both the wattage and the height of the bulbs was varied, so that about the same foot-candles of light illuminated the sample. Observation indicated that frosted lamps were poorest, blue daylight bulbs medium, and the lamps with corrective filters best in bringing out the natural colors of the tomatoes.

In the actual comparisons of the lamps the results were not as significant as expected. The graders seemed to match U. S. No. 1's (best colored tomatoes) with U. S. No. 2's under the different lamps, and separated out the best colored tomatoes for U. S. No. 1's. In other words, they did not maintain the same color line for U. S. No. 1's under the different lamps. All graders were very positive in their preference for grading tomatoes under daylight lamps, and stated that the frosted bulbs (yellowish white) caused fatigue. In the actual grading the tomatoes were separated into samples of 20 fruits which had either a high percentage of U. S. No. 1's (100–75 per cent), a medium percentage of U. S. No. 1's (55–45 per cent), or a low percentage of U. S. No. 1's (30–0). The remaining fruits in the samples were U. S. No. 2's. Some selected tests from this study will be found in Table I.

It is evident from Table I that there are a greater number of mistakes for the frosted bulb than any of the other types of lamps. These mistakes were of two kinds, namely, the placing of U. S. No. 2's in

TABLE I—ACCURACY OF TOMATO GRADING UNDER ARTIFICIAL LIGHT AS COMPARED TO DAYLIGHT. DATA GIVEN IN MISTAKES PER SAMPLE

Type of Light*	Foot-candles†	Percentage of U. S. No. 1's					
		High		Medium		Low	
		Mistakes per Sample	Fruits per Sample	Mistakes per Sample	Fruits per Sample	Mistakes per Sample	Fruits per Sample
Frosted bulb..	95	5	20	4	40	8	20
Whiterlite lamp	72	2	—	5	—	6	—
Daylight lamp.	74	2	—	0	—	5	—
Frosted bulb..	95	1	40	4	60	4	40
Daylight lamp.	74	3	—	0	—	2	—
Frosted bulb..	95	9	40	8	60	2	40
Daylight lamp.	74	1	—	6	—	3	—
Frosted bulb..	50	12	60	2	20	11	60
Whiterlite lamp	50	3	—	4	—	23	—
Daylight lamp.	50	4	—	2	—	22	—
Frosted bulb..	50	11	60	2	20	4	60
Whiterlite lamp	50	3	—	2	—	2	—
Daylight lamp.	50	2	—	2	—	3	—
Algebraic sum of mistakes							
Frosted bulb	—	—38‡	220	—8	200	+29‡	220
Whiterlite lamp.....	—	—6	140	+1	80	+31	140
Daylight lamp.....	—	—4	220	+10	200	+25	220

*Frosted bulb approximately 2700°K.
Whiterlite lamp approximately 5400°K.
Daylight lamp approximately 6300°K.
†Obtained by means of a Weston 603 Type of Illuminator which uses a Weston phototronic cell.
‡+Grading of No. 2's as No. 1's as compared to daylight.
—Grading of No. 1's as No. 2's as compared to daylight.

U. S. No. 1's, which is indicated as a plus (+), and the placing of U. S. No. 1's in U. S. No. 2's, which is indicated by a minus (–). In the algebraic sum of mistakes where there were about equal numbers of U. S. No. 1's and U. S. No. 2's, there was a tendency under a frosted bulb to put U. S. No. 1's in U. S. No. 2's, while with the other lamps there was the opposite tendency.

The use of some type of daylight lamps is essential in grading tomatoes under poor light conditions. Such lamps will also be found most useful in the canning factory at the filling table, or any other place where tomatoes are selected on a color basis. Correctly chosen lamps would also help in other types of grading of agricultural products where consideration is given to color.

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Some Effects of Nitrogen, Phosphorus and Potassium on Vascular Anatomy of Tomato Hypocotyls

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ABSTRACT

This paper will be published elsewhere.

The Effect of Nutrients on the Water Relations of Tomato Plants[1]

By W. B. Mack and G. J. Stout, *Pennsylvania State College, State College, Pa.*

THE preliminary experiments described in this report were concerned with certain interrelations of water and nitrogen in the growth and fruiting of tomato plants under conditions among which either water supply or nitrogen could be made limiting conditions for growth. The purpose of this report is to call attention specifically to variation in water content of plants as a factor in their behavior with reference to different mineral nutrient conditions, especially when these nutrient conditions bring about considerable differences in the growth of the plants.

It is a commonplace observation that plants grown rapidly with abundant water may exhibit symptoms of water deficiency even when there is a plentiful supply of water available to the roots. With a soil or other substratum in which water movement is relatively slow or in which the extension of the root system of plants is limited, such water deficiencies in the plant tissues may conceivably be sufficient to exert a clearly recognizable influence on the behavior of the plants. Obviously such influences might be accentuated by nutrient supplies which favor relatively rapid growth. These experiments were performed, therefore, to find out to what extent the moisture content of tomato plants might vary when available soil moisture was present, though differing somewhat in amount as a result of the different rates of water loss of the plants, and, if such variations in water content occurred, how they were related to blossoming and fruit production.

In these experiments, tomato plants of a Certified Marglobe strain were grown in 2-gallon glazed earthenware crocks containing either clay-loam soil or rotted manure; those with soil were supplied with different amounts of nitrogen, phosphorus, and potassium, as chemically pure sodium nitrate, calcium monophosphate, and potassium chloride, respectively. The crocks of soil each contained 16 pounds of Hagerstown clay loam, of which the pH at the beginning of the experiment was 7.5, and which had been passed through a soil shredder and a 3-mesh screen. The moisture content at the time of weighing was 13.3 per cent of the weight of the dry soil, and the maximum capillary capacity was 46.6 per cent. Previous measurements on soils of the same type showed the wilting coefficient to be about 7 per cent. Crocks containing manure had 10 pounds of thoroughly composted, shredded horse manure, of which the moisture content was 229.0 per cent of the weight of the dry matter present, and the maximum capillary capacity was 266.3 per cent. The amounts of manure and soil which were used filled the crocks to within about 2 to 2½ inches of the top. About ¾ inch of thoroughly washed crushed limestone, slightly coarser than 3-mesh, was placed on the surface of the soil or

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manure in each crock, to counterpoise the crocks and to prevent evaporation of water from the medium beneath.

The unit application of each nutrient consisted of 3.0 grams of $NaNO_3$, 3.7 grams of $CaH_4 (PO_4)_2$, and 0.8 grams of KCL per crock, mixed thoroughly with the soil before it was placed in the crock. These materials supplied 0.518 grams of nitrogen, 2.072 grams P_2O_5, and 0.518 grams K_2O respectively. The ratio of plant foods with a unit application of the three nutrients was thus 1:4:1, a ratio found by field experiments to be nearly optimum for tomatoes on the soil used. The nitrogen application of 3.0 grams per crock was sufficient to make the NO_3 concentration of the soil solution 820 parts per million immediately after watering, when the maximum amount of water was present. There were nine combinations or series of treatments, as follows: (1) Manure only, (2) N, P, K; (3) P, K; (4) 4N, P, K; (5) N weekly, P, K; (6) N, K; (7) N, 4P, K; (8) N, P; (9) N, P, 4K. (The symbols N, P, and K indicate the unit applications of each nutrient, respectively.) In all combinations with the amount of nitrogen as the variable, 12 plants constituted the series at the beginning; six plants made up each of the other series, except manure, which had 13 at the beginning.

The plants used in the experiment had been grown in a mixture of composted soil and manure as for field planting. The seeds were sown thickly in flats; seedlings were transplanted when about 2 inches tall to other flats at distances of 1½x1½ inches, and 2 weeks later were transplanted again to 4-inch clay pots. They were selected carefully for uniformity, and were about 10 inches tall on June 2 when they were set into the crocks. Any blossom clusters which could be detected were removed at that time so the fertilizers might be influential in the development of all blossoms which appeared during the experiment.

The plants were placed in the open and were fully exposed to the sun at all times except in the very late afternoon. The crocks at first were uncovered, but after a 2½-inch rainfall had occurred in a single night, mulch-paper caps were provided and rain was excluded thereafter. Watering was done with rain water which was drained into barrels, which had been thoroughly leached with water, from a section of the glass roof of the greenhouse, and which was stored in glass carboys; the amount added was that needed to bring the average moisture content of the soil in each crock to 41.6 per cent, or nearly 90 per cent of saturation, and that of the manure to 294.7 per cent, or 117 per cent of saturation. These percentages required approximately 2 kilograms more water than that originally present in the crocks with soil, and 1 kilogram more in those with manure. Water was added to all crocks whenever the moisture content of any crocks approached an arbitrary minimum of 10 per cent for the soil and 175 per cent for the manure, or approximately 21 and 65 per cent of saturation, respectively, as determined by daily weighing. On a few occasions, the moisture content fell below these limits in an occasional crock, because of very rapid water loss. During the early part of the experiment, when the plants were small, watering was necessary only every few days, but later, when the plants were larger and the temperature was high, water had to be applied daily. When water was

applied, free water usually stood on the surface for periods ranging from a few minutes to a half hour. All plants were watered whenever any plants required it, so that all series in soil were made uniform with respect to water content whenever water was applied. The procedure in watering was that of pouring into the crock sufficient water to replace that lost since the previous watering. This was recognized not to maintain a uniform moisture content for the different series, because of differences in growth and water utilization, brought about by the different fertilizers. It was chosen, however, as being more nearly representative of field conditions where rain or irrigation water penetrates the soil through the surface only after this is saturated with water. It may be pointed out in this connection that the maintenance of uniform moisture conditions is practically impossible in media in which water movement is slow and with plants which use considerable quantities, without introducing a region of free water which soon becomes accessible to the roots of plants in the cultures. In such a case the conditions established are more representative of water cultures than of field conditions. It was considered objectionable to water some crocks more often than others because more frequent applications tend to maintain more free water near the surface with attendant unfavorable effects upon root development and soil aeration.

Rain water was used in preference to tap water because the latter often is treated with disinfectants of which the effects on plants are not well known, but which would likely exert more influence on plants using larger quantities of water.

In determining the amount of water present in the soil, allowance was made for the weight of the plants, as estimated from the weight of representative plants removed as samples at monthly intervals.

Measurements recorded were the height of the plants every two weeks; the approximate transpiration loss during 24 days in the period of maximum growth rate; the relative leaf area at the time it was at the maximum in all except a few series, as determined by the sum of the products of maximum width and length of all leaves on each plant; moisture changes at 3-hour intervals in the leaves on two different days, beginning at 3 a.m. and continuing until 3 p.m., as determined from successive leaf samples taken with a Ganong leaf cutter, from leaves of the same age on all plants; the moisture content of blossoms at 3 p.m. on the second of these days; numbers of blossoms and fruits shed by different plants, at different times; number and weight of fruits matured, and the dates of maturity; occurrence of blossom-end rot on fruits; and the extent and circumstances of wilting, when such occurred. The moisture content of the entire plants, as measured on June 22, was estimated by washing the roots of the plants free from soil with a jet of water, then standing the plants in water until all were ready for weighing. This was done in the early afternoon of a clear day, and thus represented the moisture content of the plants with unlimited water supply, under similar conditions with reference to water loss.

Some of the data on Series 1, which was grown in manure, and Series 2, 3, 4, and 5, in which nitrogen was the only variable in the nutrient supply, are presented in Table I. In this table, only those

data should be related which were recorded at about the same time or during the same period. These show that growth, relative leaf area, weight of plants, moisture content, and water loss per plant, with a few exceptions, were greater with the heavier applications of nitrogen. Some of the exceptions may be found in the average daily water loss, in moisture percentage of the entire plant on June 22, and in the reduction in moisture content of the leaves between 3 a.m. and 12 m. on June 21, for Series 5, which received weekly applications of nitrogen. The plants in this series usually wilted more noticeably than did the other series in the middle of the day, even though the moisture content of the soil was above the minimum allowed. This may account to some extent for the differences in behavior of this series.

With reference to the tendency of plants to wilt, the observation is

TABLE I—INFLUENCE OF NITROGEN ON GROWTH, LOSS OF WATER, RELATIVE LEAF AREA, GREEN WEIGHT OF PLANTS, MOISTURE CONTENT OF PLANTS AND LEAVES, NUMBER AND WEIGHT OF FRUITS, OCCURRENCE OF BLOSSOM-END ROT, AND ABSCISSION OF FLOWERS OF TOMATO

	Series and Treatment				
	1 Manure	3 P, K	2 N, P, K	4 4N, P, K	5 Weekly N*, P, K
Average daily increase in height (cms) 6/15 to 8/3	1.1	0.7	0.8	1.1	1.3
Average daily increase in height (cms) 7/6 to 7/21	1.1	0.8	0.7	1.5	1.3
Index of leaf area, 7/7 (NPK=100)	105	44	100	117	127
Average daily water loss per plant (kgs) 7/8 to 8/1	0.66	0.36	0.54	0.80	0.75
Green weight of entire plant (gms) 6/22	124.3	88.5	156.5	157.3	187.5
Percentage of moisture in entire plant 6/22	87.0	86.7	87.2	87.6	85.7
Percentage of moisture in the leaves, 3 a.m., 6/21	84.7	77.8	78.4	81.6	81.2
Reduction in moisture percentage of leaves, 12 m., 6/21	3.8	1.2	3.1	4.5	3.5
Percentage of moisture in leaves 6 a.m., 7/20	81.5	78.8	79.2	80.2	80.4
Reduction in moisture percentage of leaves 3 p.m., 7/20	4.2	2.4	2.9	——	3.3
Moisture percentage of blossoms 3 p.m., 7/20	82.4	85.5	84.6	79.4	77.6
Number ripe fruits per plant up to 8/30	1.9	1.0	2.4	3.5	5.6
Total weight of ripe fruits per plant to 8/30 (gms)	106	73	215	353	386
Average weight per fruit (gms)	56	73	91	101	69
Percentage of fruit with blossom-end rot	53	0	5	21	18
Flowers shed per plant up to 7/20	1.0	0	2.3	1.0	1.0
Average green weight of plants (gms) 8/17, not including fruit	465	112	219	431	546
Average weight of unripe fruit per plant (gms) 8/17	92	6	89	296	339

*On June 23, this series had received 4 times; on July 20, 8 times; and on August 16, 12 times the basic amount of nitrogen.

interesting that a very small reduction in moisture content of leaves caused wilting in the most succulent leaves, while a considerably larger reduction caused no perceptible change in the less succulent leaves. This was observed on both occasions when moisture content of leaves was measured at three-hour intervals from before daybreak until mid-afternoon.

The number and the total yield of fruits were greater, the more nitrogen was applied, but the average weight of fruits was somewhat less in the series with weekly applications of nitrogen than in the other series in soil. The average weight of fruits in the manure series was considerably reduced by the fruits with blossom-end rot, which were usually undersized and sometimes shrunken. This disease was most prevalent in Series 4 and 5, which received the most nitrogen, but there was no significant difference between these two series in this respect. This is noteworthy in view of the fact that plants of the series with weekly applications of nitrogen wilted more frequently and more severely than did those in the other series. Plants grown in manure had most blossom-end rot, though they usually did not wilt noticeably during the period when most fruit was being produced. The wilting in the manure series was confined to a few days after they had been watered somewhat in excess by the heavy rain already mentioned, which occurred on the night of June 19 and 20.

The moisture percentage of the blossoms in mid-afternoon, on the single day when this was measured, was lower, the greater the application of nitrogen. This may be due to the competition of the leaves for the water supply of the plant, which probably was greater in plants having the larger leaf area. Low moisture content of blossoms evidently did not interfere with blossom development or setting of fruit, except in a few extreme cases.

Abscission of flowers was not closely associated with the supply of nitrogen. It was observed that very severe wilting was usually followed by the loss of a few flowers. Most of the abscission of flowers from the plants grown in manure took place soon after the period of severe wilting which was brought about by overwatering already referred to, and a considerable number of flowers with stunted corollas and partly fasciated styles appeared at about the same time. Most of the flowers which fell from the plants receiving the basic amount of nitrogen did so late in the course of the experiment, when the plants had begun to show symptoms of nitrogen deficiency. No flowers were shed from the plants which received no nitrogen, probably because growth was slow and few flowers developed.

Several observations were made, for which data are not presented here. One of these was that added phosphorus and potassium had no observable effect on any of the characteristics studied. This is specially interesting in view of the great influence of phosphorus applications on growth and yield of crops in the field on the same type of soil as that used in the crocks. Nitrogen, on the other hand, is shown to have had a controlling influence on growth and yield, a relationship which has not been found to so great a degree in field experiments on soil of the same type.

The Influence of Nitrate and Ammonium Nitrogen on the Growth of Greenhouse Tomatoes in Soils of Different Reaction

By I. C. Hoffman, *Experiment Station, Wooster, O.*

THIS paper is a report of progress on a comparison of the efficiency of nitrate of soda and sulphate of ammonia for fertilizing greenhouse tomatoes in soils of different reaction. Commercial greenhouse tomato growers in Ohio have reported varying results with these fertilizers. Most of their soils have a pH value slightly below the neutral point although some are neutral and a few are slightly above.

Laboratory investigations show that ammonium nitrogen is more efficient for tomatoes grown under alkaline conditions and nitrate nitrogen better under acid conditions. In commercial greenhouses this did not always seem to hold. In order to get additional information that would apply to these conditions, a greenhouse bed at the Ohio Station was divided into 6 plots each 6 feet by 7 feet in size and 8 inches deep. These were filled with a compost made of Wooster silt loam and cow manure and the reaction adjusted with ground limestone and sulphur so that a pair of plots had reactions, respectively of pH 7.8 to 8.0, 6.5 to 7.0, and 5.0 to 5.5 or as near as it was possible to maintain them. Sixteen potted plants were planted in each plot and grown to full maturity during an entire growing season, which is about 5½ months. The first crop was set in the beds the latter part of January and removed in July and the second crop set in August and removed early in January of each year. Frequent pH readings were made of the soil and the soils readjusted when necessary.

The basal treatment of each plot consisted of an application of well rotted cow manure at the rate of 40 tons per acre spaded in when the ground was prepared. Superphosphate and potash were applied in amounts equivalent to 1000 pounds per acre of 0–20–20 fertilizer at the same time and well worked into the soil. The nitrogen fertilizers were applied in equivalent amounts at weekly intervals after three clusters of tomatoes had set fruit. They were applied broadcast on the soil just before irrigating, which dissolved the salts and carried them into the soil. Water was applied three times each week at the rate of ½ to ¾ acre-inch per application and in periods of very high temperatures somewhat more was applied. The plants were topped at the same number of clusters and the harvesting was discontinued on all of the plots at the same time.

The variety used was the Marhio. During the progress of the experiments an occasional plant was broken or became diseased which caused its removal before the end of the season. In each case the yield of the plant was estimated, and the number of plants on which the data are computed sometimes contains a fractional plant as a result.

Table I—A presents the data collected from a fall crop and Table I—B, the average of two spring crops. The data in Table I—A show that on alkaline soil sulphate of ammonia tends to produce larger fruits and a greater total weight of fruits per plant than nitrate of

soda, although a few more fruits were set on the nitrate treated plot. The percentage of first grade fruits was somewhat higher on the nitrate than on the sulphate plot.

TABLE I—NITRATE OF SODA VS. SULPHATE OF AMMONIA FOR GREENHOUSE TOMATOES ON SOILS OF DIFFERENT REACTION

Nitrogen Form	Soil Reaction	No. Plants Surviving	Aver. Yield per Plant		Yield 1st Grade Fruits		Percentage 1st Grade Fruits per Plant	Average Wt. per Fruit 1st Grade (Ounces)
			No.	Wt. (Pounds)	No.	Wt. (Pounds)		
A. Fall Crop								
Nitrate of soda	7.8–8.0	15.5	25	6.56	17	4.53	69.3	4.16
Sulfate of ammonia	7.8–8.0	15	21	7.00	14	4.7	67.3	5.28
Nitrate of soda	6.5–7.0	14.5	23	6.75	15	4.4	64.7	4.64
Sulphate of ammonia	6.5–7.0	16	20	6.08	13	3.9	64.5	4.80
Nitrate of soda	5.0–5.5	15	26	8.04	16	4.9	61.3	4.89
Sulphate of ammonia	5.0–5.5	16	23	6.78	15	4.3	63.9	4.48
B. Spring Crop								
Nitrate of soda	7.8–8.0	15.75	28	8.40	13	3.8	45.47	4.48
Sulphate of ammonia	7.8–8.0	15.5	28	8.13	13	3.9	47.82	4.80
Nitrate of soda	6.5–7.0	15.75	25	7.21	11	3.2	44.41	4.64
Sulphate of ammonia	6.5–7.0	13.5	29	8.15	14	3.9	47.65	4.44
Nitrate of soda	5.0–5.5	16	26	7.28	13	3.5	48.30	4.32
Sulphate of ammonia	5.0–5.5	15.25	28	8.01	15	4.3	53.61	4.48

On the neutral soils the nitrate produced three more fruits per plant and totaled 2/3 pound per plant greater weight of fruit than the sulphate plot although the weight per fruit and the percentage in first grade were nearly the same. On the acid range the nitrate produced more fruits and a greater total weight per plant than the sulphate. The individual fruits were also slightly larger, but the percentage of first grade fruits was somewhat higher in the sulphate plot which indicates that the shape and solidity of the fruits on the sulphate plot was somewhat superior to those on the nitrate plot.

Table I—B presents the data averaged for two spring crops on unsterilized soil, and shows that the nitrate treated plot produced slightly greater total weight and the same number of fruits per plant as the sulphate on the alkaline soil. The sulphate treated plot produced the larger percentage of first grade fruits which were somewhat larger than those on the nitrate plot.

On the neutral soil plots the sulphate treatment produced the greater number of fruits per plant, a greater total weight of fruits, and a higher percentage of first grade fruits, although the average weight per fruit was a little less. On the acid soil, the sulphate treatment proved superior to the nitrate treatment from all standpoints, which is somewhat contrary to the results of laboratory experiments.

There is at present another fall crop in production in these plots. Preliminary observations indicate that the results will be similar to the previous fall crop reported in Table I—A. The data are not yet complete so definite statements can not be made.

The fall crops were grown on freshly sterilized soil, while the spring crops were not, as the sterilizing is done in the summer between crops. Death of the nitrifying organisms did not prevent the efficient use of the ammonia by the tomato plants on the alkaline soil, but apparently its use was less effective on the neutral and acid soils. After the nitrifying organisms had time to multiply and again become effective in the spring the ammonia was just as effective as the nitrate if not better under these conditions. The indications from the present stage of this experiment are that sulphate of ammonia is just as efficient in supplying nitrogen for greenhouse tomatoes as nitrate of soda for soil reactions that are expected in most well managed greenhouses, except possibly on recently sterilized soils moderately acid in reaction.

The Influence of Soil Reaction upon the Growth of the Tomato Plant

By M. M. PARKER, *Virginia Truck Experiment Station, Norfolk, Va.*

THE tomato plant is commonly considered tolerant to a degree of soil acidity that would severely injure many of the cultivated vegetable crops and it presumably is not adversely affected when grown in neutral or slightly alkaline soil (1). However, tomatoes grown this past summer on the soil reaction plats at the Virginia Truck Experiment Station demonstrated that the soil reaction is a factor that should not be ignored if optimum plant growth is to be obtained. The soil in these plats had been made strongly acid in 1928 by the use of sulphate of ammonia which in turn was followed by applications of hydrated lime so that a reaction range from pH 4.4 to pH 6.8 was obtained. All treatments were in triplicate. The soil in all of the plats was fairly uniform in fertility with the exception of two of the plats in the most acid series, which had a somewhat low soil organic matter content.

Marglobe tomato seedlings grown in a suitable field soil were transplanted in midsummer to all of the plats after a complete fertilizer mixture had been applied. Excellent growing conditions prevailed during the forepart of the season, but excessive rainfall in August and September produced conditions which interfered with fruit formation and caused the rotting of so many of the fruit that had set under favorable conditions that it was decided to record vine growth rather than weight of fruit so that a more reliable growth index could be obtained.

The plants were pulled and the individual green weights recorded shortly before killing frosts. Soil reaction readings were made during the growing season and a final one just previous to the harvest.

The reaction of the tomato plant to soil acidity was most noticeable on the strongly acid soils, and its injurious effects were particularly aggravated on the soils with a low organic content (less than 2 per cent). At soil reactions from pH 4.4 to pH 5.0 the growth rate of the plants was greatly retarded resulting in a dull grayish green colored plant with limited foliage located mainly at the ends of hard slender otherwise defoliated branches. The average weight of the plants grown in soils with a reaction between pH 4.8 and pH 5.0 was slightly less than it was between the reactions of pH 4.4 and pH 4.6, but the plants in both plats were so severely injured that the difference was of no material consequence. A significant increase in plant weight was recorded when the soil acidity decreased to a reaction between pH 5.2 and pH 5.4. The plants in these plats were normal in appearance and type of growth, but they were still considerably smaller than the plants grown on soils with reactions from pH 5.5 to pH 5.7. Between the soil reactions of pH 5.5 and pH 6.4 significant increases in plant weight were obtained over that secured in the more acid soils, and it was in this range that optimum plant growth was recorded. The greatest average plant weight occurred

between the soil reactions of pH 6.2 and pH 6.4, but it was not significantly greater than that secured between the reactions of pH 5.5 and pH 6.2. Soils less acid than pH 6.7 evidently were not conducive to the best growth of the plant since a significant decrease in weight occurred between pH 6.75 and pH 6.85. This decrease in growth might be explained by a lack of balance in the plant nutrients as the soil approached neutrality.

TABLE I—THE EFFECT OF SOIL REACTION UPON THE WEIGHT OF TOMATO VINES

pH Range	Average Green Wt. per Vine (Pounds)
4.45–4.6	$1.88 \pm .09$
4.8–5.0	$1.62 \pm .11$
5.2–5.4	$2.10 \pm .11$
5.55–5.75	$3.44 \pm .12$
6.0–6.2	$3.13 \pm .21$
6.2–6.4	$3.81 \pm .13$
6.75–6.85	$2.86 \pm .12$

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Injurious Effects of Certain Nitrogenous Fertilizers on the Growth of Spinach

By M. M. PARKER, *Virginia Truck Experiment Station, Norfolk, Va.*

MANY of the soils used in the Norfolk, Virginia, region for the production of fall spinach may be classified as border line soils in that their reaction is frequently at such a point that a slight decrease in soil acidity makes them more suitable for the growth of this plant; or the reverse may be true and an increase in acidity occasioned by one of several factors causes crop failure.

One such factor that may increase the soil acidity and which the grower commonly fails to take into consideration is the effect of the source of the nitrogen in a complete fertilizer mixture upon the soil reaction. This is true whether it is applied before planting the crop, or as a top dresser, which quite frequently may consist of nitrogenous fertilizers alone and which may in some cases be applied several times during the growing season.

To determine the effect of some of the various carriers of nitrogen in a complete fertilizer upon the spinach plant when all of the fertilizer was applied before planting[1] an area was selected for the test which was considered a representative fall spinach soil and which normally produces good yields of spinach. Its reaction on August 19, 2 weeks before planting the crop, was pH 5.2 but since this was considered somewhat too acid for normal growth of the plant, it was limed with dolomitic limestone at the rate of 1500 pounds to the acre.

A second area with a reaction of pH 5.9 was selected for a later planting. No lime was added to this soil as the reaction was considered sufficiently high. On both soils a heavy green manurial crop was turned under in sufficient time for decomposition to be nearly complete before planting the spinach.

The fertilizer, analyzing 6 per cent nitrogen, 8 per cent phosphoric acid, and 5 per cent potash, was applied at the rate of 1500 pounds to the acre after the spinach beds were formed and was thoroughly incorporated with the top three inches of soil by means of a spike drag.

Five separate mixtures were employed, each of which obtained its phosphorus from 19.44 per cent superphosphate and its potash from 48 per cent muriate of potash. The nitrogen was furnished in Mixture 1 by sulphate of ammonia alone, in Mixture 2 equally from nitrate of soda and sulphate of ammonia, in Mixture 3 equally from sulphate of ammonia and dried blood, in Mixture 4 from dried blood alone, and in Mixture 5 from cyanamid.

The fertilizer materials with the exception of the nitrate of soda-sulphate of ammonia mixture were applied 12 days in advance of planting, allowing 3 days for every 100 pounds of cyanamid used.

The early planting was made August 30, and the late one on Sep-

[1]In the late planted lot the nitrate of soda-sulphate of ammonia mixture without phosphorus or potash was applied only as a top dresser in two applications.

tember 12. Favorable germination and growing conditions prevailed until shortly before the first planting was of sufficient size to harvest when high temperatures and a prolonged drought almost completely arrested growth until November 4, when the drought was broken.

EFFECT OF THE SOURCE OF NITROGEN ON THE COLOR AND TYPE OF PLANT GROWTH

Plants on the sulphate of ammonia plat were flat, dwarfed, and very dark green, even during the early period of growth and during periods of warm weather when foliage is normally light green in color. Blood produced a rather upright type of growth which was slightly yellowish green in color during the early period of growth, even a more pronounced yellow during the period of drought, and a darker green at lower temperatures and with more abundant rainfall. Cyanamid produced a flat growing, dark green colored plant which was not appreciably changed in color by rainfall or temperature. The margins of some of the leaves, however, turned a distinct yellow color during the period of prolonged drought. The two mixtures nitrate of soda-sulphate of ammonia, and sulphate of ammonia-blood produced a type of growth intermediate between that fertilized with cyanamid and with blood. The plants were not as dark in color as those on the cyanamid plats, but they exhibited a more upright type of growth. When matched with Ridgeway's color standards the foliage color range during the early part of the season was as follows on the differently treated plats: Cyanamid, cedar green; sulphate of ammonia-nitrate of soda, cedar green; sulphate of ammonia, grass green; sulphate of ammonia-blood, deep dull yellow green; and blood, light elm green.

The effect of the different sources of nitrogen on the soil reaction and yield of marketable spinach is given in Tables I and II.

The reading taken on December 10, after the harvest of plants showed the greatest degree of soil acidity when sulphate of ammonia furnished all of the nitrogen. For the early planted area it was .3 of a pH lower than the original reaction although 1500 pounds of dolomitic limestone had been applied before the crop was planted. Next highest in acidity was the sulphate of ammonia-blood mixture which gave a reading similar to the initial reaction of the soil. The areas treated with the sulphate of ammonia-nitrate of soda mixture, with blood and with cyanamid were appreciably higher in reaction than those treated with fertilizer containing sulphate of ammonia alone or with blood and sulphate of ammonia. It is probable that the limestone did not have sufficient time to react to any degree of completeness for it failed to bring about as great a change in reaction as was to be expected in areas treated with the slightly acid materials as the blood and the nitrate of soda-sulphate of ammonia mixture, or with the alkaline cyanamid fertilizer. The fact that the area treated with cyanamid was not highest in reaction may have been due to soil heterogeneity or to imperfect sampling in the field.

As would be expected, the spinach plant, which is not acid tolerant, responded with variations in yield depending upon the degree of soil acidity. Those materials which produced the greater degree of soil

acidity returned the lowest yields. Sulphate of ammonia and the sulphate of ammonia-blood mixture gave yields considerably lower than those produced on the plats treated with cyanamid or with the nitrate of soda-sulphate of ammonia mixture. The relatively low yield in the early planting of the plants fertilized with blood as the only source of nitrogen was probably due to lack of available nitrogen rather than to soil reaction, since they made rapid growth until seriously affected by drought.

TABLE I—CHANGE IN SOIL REACTION AND YIELD OF SPINACH WHEN FERTILIZED WITH DIFFERENT SOURCES OF NITROGEN IN A COMPLETE MIXTURE

Planted Aug. 30, 1934 (Early Planting) Harvested Dec. 1, 1934

Source of Nitrogen	Initial Reaction (pH)	12/10/34 Final Reaction (pH)	Yield (Pounds per Acre)
Sulphate of ammonia	5.2	4.9	5141
Nitrate of soda and sulphate of ammonia	5.2	5.6	6824
Sulphate of ammonia and blood	5.2	5.2	5823
Blood	5.2	5.6	5664
Cyanamid	5.2	5.5	6873

The initial readings of the late planted area were taken in September when the soil moisture content was much higher than during the greater part of the growing period during which very little rain fell. This probably accounts for the relatively high initial pH readings.

The effects of the different sources of nitrogen are in general even more striking than with the earlier planting. Plants on a considerable portion of the area treated with sulphate of ammonia were killed during the early stages of growth by adverse conditions associated with a very low soil reaction (pH 4.9). The remainder grew slowly and gave a very low yield to the acre. The yield was also materially reduced by the mixture of sulphate of ammonia and dried blood, which lowered the soil reaction considerably. Cyanamid as the source of nitrogen gave the highest soil reaction and largest yield of spinach. The quality, however, was impaired to some extent by the yellowing of the margins of many of the mature leaves during the period of prolonged drought.

TABLE II—CHANGE IN SOIL REACTION AND YIELD OF SPINACH WHEN FERTILIZED WITH DIFFERENT SOURCES OF NITROGEN IN A COMPLETE MIXTURE

Planted Sept. 12, 1934 (Late Planting) Harvested Dec. 15, 1934

Source of Nitrogen	Initial Reaction (pH)	12/17/34 Final Reaction (pH)	Yield (Pounds per Acre)
Sulphate of ammonia	5.9	4.5	1319
Nitrate of soda and sulphate of ammonia	5.9	5.8	5404
Sulphate of ammonia and blood	5.9	5.0	4415
Blood	5.9	5.4	5359
Cyanamid	5.9	5.9	6238

A Study of the Temperature, Day Length, and Development Interrelationships of Spinach Varieties in the Field

By VICTOR R. BOSWELL, *U. S. Department of Agriculture, Washington, D. C.*

INTRODUCTION

SPINACH growers and those familiar with the crop, particularly in the Middle Atlantic States, know that spinach will shoot to seed quicker in a warm season than in a less warm one and that it will stand longer when planted early than if planted even a short time later. Since a number of papers upon temperature and day length effects in the field upon other crops had presented such interesting results, it appeared that it might be a simple matter to reduce to numerical terms certain of the day length, temperature, and developmental relationships of this crop. Also, a careful evaluation of the relative "long standing" properties of several important varieties is of obvious interest.

There recently has been an important revival of commercial and scientific interest in varieties of all kinds of crop plants, particularly in the details of their behavior in different environments. Accurate knowledge of varietal responses to single factors or combinations of factors often enables one to predict the adaptability of a variety to new places or conditions of culture and to recommend methods of handling it.

This paper presents a brief summary of an inquiry into the "long standing" qualities of 17 crops of seven varieties of field-grown spinach as affected by temperature and day length in the several locations and seasons in which they were grown. Moisture supply is believed not to have been an important factor since an apparently adequate amount of winter and spring rain or of irrigation water was received by all crops.

MATERIALS AND METHODS

The data on dates of sowing, emergence of plants, and appearance of seed stalks were derived from two sources: (A) Those for crops grown near Washington, D. C., at College Park, Maryland, from 1926 to 1928, are from the paper on spinach varieties by Farley (1) and supplemented by him; (B) the dates for the crops at the other locations listed (see Table II) were obtained since 1930 incidental to the standardization and description studies made cooperatively by the Bureau of Plant Industry near Washington, D. C., at Arlington Farm, Virginia, and the Agricultural Experiment Stations of California at Davis, of Texas at Winter Haven, and of Cornell University at Ithaca, New York.[1]

The figures on day length were calculated from data in the "Nautical Almanac" (5) and on temperature from Climatological Data (4).

[1]Data on dates were obtained by G. W. Scott, L. R. Hawthorn, and Paul Work, respectively, of the Agricultural Experiment Stations named, and by Roy Magruder and the writer, of the Bureau of Plant Industry.

By the procedure described by Livingston (2) remainder and exponential index summations were calculated above base temperatures of 32, 36, 40, 45, and 50 degrees F. The remainder index was calculated for each day as the number of degrees by which the daily mean temperature exceeded the arbitrary base temperature. Only positive values were summed in obtaining the remainder index summations for the time from emergence to seed stalk appearance. The mean of the minimum and maximum for a single day was considered the daily mean temperature.

In calculating the exponential indices, the daily remainder index was first determined, then this value was multiplied by an exponent derived from the more or less arbitrary assumption that the rate of the process being studied will be doubled for each 18 degrees F rise in temperature. For example, suppose that calculations are being made above a base line of 36 degrees F, on the assumption that there is no appreciable growth and development below that temperature. A daily mean temperature of 54 degrees represents a remainder index of 18, and an exponential index of 36. Likewise a daily mean of 72 degrees represents a remainder of 36, but an exponential index of 144. The exponential values were summed in the same manner as the remainder indices.

The remainder and exponential indices were determined separately for each variety in the several locations for each seasonal group. The standard deviation and coefficient of variation were then calculated for each group of values. The standard deviation was determined by the following formula:

$$\sqrt{\frac{\Sigma X^2 - (\Sigma X)^2}{n-1}}$$

When the C. V.'s of the temperature accumulations calculated above each base temperature were compared by inspection, it was quite evident that the lowest values resulted from accumulating remainder indices above a base temperature of 36 degrees. This was interpreted as an indication that those accumulations most nearly reflected or coincided with the response of the plants to temperature, and so are here used in an attempt to evaluate response to temperature. For a discussion of this method of choosing a base temperature, see Magoon and Culpepper (3).

It is admitted that the temperature data used in these studies were not obtained near the soil surface in the immediate position of the plants. It is conceivable that appreciable errors may be involved as a result of highly localized temperature conditions immediately about the plants. Differences in slope, character of soil surface, and wind movement doubtless result in appreciable differences of air temperature surrounding low-growing plants during variable periods of time.

Statistical methods were supplemented by graphic analysis of the meteorological conditions that occurred during the development of each variety of each crop. Remainder and exponential indices were plotted cumulatively for 5-day intervals and studied with relation to the day length curve and daily mean temperature curves on the same graph, all curves being accurately oriented with reference to calendar

date. On account of differences in day length curves, only data for crops grown in the same latitude could be plotted on the same graph. The daily fluctuations of the temperature curves were smoothed by calculating 5-day overlapping averages. Comparable curves for each variety in each year were compared not only as they stood with reference to calendar date, but were also transposed to the same initial point in order to better observe the several curve characteristics in relation to varietal behavior and environmental conditions. It is re-

TABLE I—COMPARISON OF METHODS OF CALCULATING TEMPERATURE ACCUMULATIONS BETWEEN PLANT EMERGENCE AND SEED STALK APPEARANCE IN SEVEN VARIETIES OF SPINACH GROWN IN DIFFERENT REGIONS AND SEASONS

	Virginia Savoy	Bloomsdale Savoy	Viroflay	Long Standing Bloomsdale	Nobel or Gaudry	Princess Juliana	King of Denmark
Long Day—Spring Crops (8)							
Days to first seeders							
Min.	19	23	24	38	39	45	43
Max.	46	50	52	53	58	59	69
Mean	35.5	39.7	39.6	44.8	49.1	51.4	58.7
C. V. (Per cent)	27.3	21.8	22.9	11.5	9.9	9.4	12.2
Remainder sums (Day-degrees)							
Min.	515	660	703	922	959	959	1119
Max.	953	1036	992	1276	1431	1625	1717
Mean	739	863	857	1126	1157	1232	1482
C. V. (Per cent)	20.5	12.5	11.4	12.5	14.0	16.7	13.1
Exponential sums (Day-degrees)							
Min.	1569	2090	2177	2478	2430	2430	3013
Max.	2861	3261	3036	5007	5007	6638	6182
Mean	2021	2465	2436	3581	3563	3780	4822
C. V. (Per cent)	21.6	14.2	10.7	24.6	23.9	34.5	21.6
Short Day—Winter Crops (9)							
Days to first seeders							
Min.	61	69	69	78	78	89	80
Max.	181	183	184	190	205	209	213
Mean	109.9	114.1	125.4	120.4	122.7	145.9	146.3
C. V. (Per cent)	41.2	40.3	33.9	27.4	34.7	30.7	33.9
Remainder sums (Day-degrees)							
Min.	1014	1136	1198	1391	1263	1527	1439
Max.	1923	2049	2322	3093	3364	3502	3364
Mean	1449	1565	1772	2146	2073	2259	2269
C. V. (Per cent)	22.4	22.0	22.4	25.5	37.8	29.5	26.8
Exponential sums (Day-degrees)							
Min.	2027	2126	2303	3037	2697	2946	3162
Max.	5715	6092	7002	9033	10178	11220	10178
Mean	3206	3610	4146	5241	5262	5689	5664
C. V. (Per cent)	38.4	38.9	38.2	57.1	52.0	46.6	40.2

TABLE II—TIME AND REMAINDER INDEX SUMS FROM PLANT EMERGENCE TO SEED STALK APPEARANCE IN SEVEN VARIETIES OF SPINACH GROWN IN DIFFERENT REGIONS AND SEASONS

Place		Virginia Savoy	Bloomsdale Savoy	Viroflay	Long Standing Bloomsdale	Nobel or Gaudry	Princess Juliana	King of Denmark
				Long Day—Spring Crops				
Near Washington, D. C., 39° N. Lat., 6 crops	Days to first seeders							
	Min.	19	23	24	39	39	45	43
	Max.	46	50	52	53	57	59	63
	Mean	35	39	40	46	50	52	57
	Remainder sums (Day-degrees)							
	Min.	515	660	703	1105	959	959	1119
	Max.	953	1036	992	1176	1431	1625	1715
	Mean	718	853	857	1217	1198	1264	1427
Ithaca, N. Y., 42° 30′ N. Lat., 2 crops	Days to first seeders							
	Min.	29	35	34	38	39	45	62
	Max.	45	47	45	47	53	53	69
	Mean	37	41	40	43	46	49	66
	Remainder sums (Day-degrees)							
	Min.	738	867	843	922	1003	1064	1580
	Max.	867	922	867	967	1064	1207	1717
	Mean	803	895	855	945	1034	1136	1649

Short Day—Winter Crops

Near Washington, D. C., 39° N. Lat., 3 crops	Days to first seeders							
	Min.	159	170	180	—	—	198	207
	Max.	181	183	184	(190)*	(205)*	209	218
	Mean.	172	178	183	—	—	205	213
	Remainder sums (Day-degrees)							
	Min.	1147	1207	1278	—	—	1532	1803
	Max.	1855	1986	2120	(2229)*	(1989)*	2728	2830
	Mean.	1543	1615	1685	—	—	2123	2305
Davis, Calif., 38° 30′ N. Lat., 3 crops	Days to first seeders							
	Min.	61	69	69	78	77	89	80
	Max.	97	98	122	126	125	131	132
	Mean.	79	79	91	102	93	106	103
	Remainder sums (Day-degrees)							
	Min.	1014	1136	1198	1391	1263	1527	1439
	Max.	1288	1309	1857	1919	1905	2018	2035
	Mean.	1158	1214	1462	1649	1512	1713	1652
Winter Haven, Texas, 28° 30′ N. Lat., 3 crops	Days to first seeders							
	Min.	67	79	95	97	124	107	111
	Max.	87	92	114	131	127	141	132
	Mean.	78	85	102	116	126	126	123
	Remainder sums (Day-degrees)							
	Min.	1250	1620	2059	2059	2550	2340	2462
	Max.	1923	2049	2322	3039	3364	3502	3364
	Mean.	1647	1866	2168	2617	2957	2941	2851

*Only 1 crop.

gretted that publication costs do not permit here a reproduction and detailed discussion of these graphic studies since, after all, they are more illuminating than tabular data.

Results and Discussion

On account of the arrested or retarded growth and development during cold periods of winter, fall and winter sown crops require a much longer time to attain market size than do spring sown crops. The data on the eight spring grown crops and the nine fall or winter sown crops are therefore presented separately.

Of perhaps first interest is the relative long standing characters of the several varieties as summarized under "Days to first seeders" in Table I. There were very few exceptions among the 17 individual crops in which the order of shooting to seed varied from that in the table. The actual number of days varied widely, however, from year to year and from place to place for both the spring and the fall and winter crops. (See Table II.) Thus, even though length of vegetative period varies enormously as a result of external conditions, *relative* long standing tendency among the varieties is very firmly established as a varietal character.

Table I presents minimum, maximum, and mean summations of remainder and exponential indices for different varieties, together with the coefficients of variation of each group of summations that is averaged. It will be noted that in every case but one the C. V.'s of the exponential summations are higher than for remainder summations, and in some cases very much higher. Thus it appears that remainder sums are superior to the exponential sums as a measure of heat requirement. In the discussion that follows, further consideration of exponential sums will be omitted.

Observations on numerous crops of spinach have led to the supposition that in crops grown under similar day length, seed stalks would appear upon the accumulation of a more or less definite amount of effective heat; and that under a definite day length shooting to seed would occur upon the accumulation of a smaller amount of heat than if the crop were grown under a shorter day. A glance at Tables I and II will show that this is true if we compare the spring crop group as a whole, with the fall and winter crop group, using remainder index sums as the measure of heat. The mean heat summation of the several crops of each variety in the fall and winter (short day) group is consistently about 100 per cent greater than for the corresponding variety in the spring (long day) group.

Proceeding now to a consideration of individual crops and varieties between seasonal groups, and within a seasonal group, our supposition is found to be frequently contrary to the facts. For the varieties Virginia Savoy, Bloomsdale Savoy, and Viroflay no temperature summation for the long day season exceeded the minimum summation for the short day. But in the varieties Nobel or Gaudry, Princess Juliana, and King of Denmark there were seven cases wherein the temperature accumulations for the shorter day crops were less than for the maximum accumulation of a long-day crop of the same variety. In one case a crop of fall-sown, wintered-over Princess Juliana went

to seed on a total heat accumulation of 1532 day-degrees 198 days after emergence of the seedlings, in contrast to another crop that was spring sown but which did not shoot to seed until 1625 day-degrees had accumulated over 49 days of a longer day-length. It so happened that the 1931 and 1934 crops at Arlington Farm, Virginia, emerged from the soil on April 21 and April 19, respectively (Table III), thus insuring practically identical day length conditions for the two crops. The temperature curves for the two seasons were remarkably similar, for the first three weeks. Still there was a marked difference in the temperature accumulations to time of shooting to seed in most varieties.

In Table III, detailed data on temperature and day length are presented for four of the seven varieties studied. Viroflay and Long

TABLE III—TIME AND CONDITIONS OF TEMPERATURE AND LIGHT BETWEEN PLANT EMERGENCE AND SEED STALK APPEARANCE OF FOUR VARIETIES OF SPINACH GROWN IN DIFFERENT REGIONS AND SEASONS

Region	North Latitude	Approximate Emergence Date	Days to Seed Stalk Appearance	Mean Temperature (Degrees F)	Day Length		Remainder Index Sums (Day-degrees)
					Minimum (Hrs)	Maximum (Hrs)	
			Virginia Savoy				
D. C.	39°	3-24-27	46	51.5	12.2	14.1	714
D. C.	39°	4- 8-28	38	53.7	12.9	14.3	673
D. C.	39°	4-21-31	38	61.1	13.3	14.7	953
D. C.	39°	4- 1-32	45	55.5	12.6	14.3	879
D. C.	39°	5- 1-33	19	63.1	13.8	14.4	515
D. C.	39°	4-19-34	24	60.0	13.3	14.2	575
N. Y.	42° 30′	4-20-31	45	54.3	13.5	15.2	867
N. Y.	42° 30′	5-10-32	29	61.4	13.4	15.2	738
Calif.	38° 30′	12-24-30	80	50.7	9.4	11.6	1172
Calif.	38° 30′	12-22-31	97	49.3	9.4	12.4	1288
Calif.	38° 30′	2- 8-33	61	52.6	10.4	12.9	1014
D. C.	39°	10-17-26	176	42.5	9.4	13.0	1147
D. C.	39°	10-11-27	181	45.0	9.4	12.9	1628
D. C.	39°	10-13-31	159	47.7	9.4	12.1	1855
Tex.	28° 30′	1- 4-31	67	52.7	10.4	11.9	1250
Tex.	28° 30′	12-14-31	81	59.7	10.2	11.6	1923
Tex.	28° 30′	10-24-32	87	56.3	10.2	10.6	1768
			Bloomsdale Savoy				
D. C.	39°	3-24-27	50	52.3	12.2	14.1	814
D. C.	39°	4- 8-28	43	55.4	12.9	14.3	833
D. C.	39°	4-21-31	40	61.9	13.3	14.7	1036
D. C.	39°	4- 1-32	48	56.2	12.6	14.4	970
D. C.	39°	5- 1-33	23	64.7	13.8	14.5	660
D. C.	39°	4-19-34	32	61.1	13.3	14.4	805
N. Y.	42° 30′	4-20-31	47	55.6	13.5	15.2	922
N. Y.	42° 30′	5-10-32	35	60.8	13.4	15.2	867
Calif.	38° 30′	1-10-31	70	52.2	9.6	12.0	1136
Calif.	38° 30′	12-22-31	98	49.3	9.4	12.4	1309
Calif.	38° 30′	2- 8-33	69	53.4	10.4	13.3	1198
D. C.	39°	10-17-26	181	42.7	9.4	13.3	1207
D. C.	39°	10-11-27	183	45.0	9.4	13.0	1651
D. C.	39°	10-13-31	170	47.7	9.4	12.6	1986
Tex.	28° 30′	1- 8-31	79	56.5	10.4	12.4	1620
Tex.	28° 30′	12-12-31	85	60.1	10.2	11.7	2049
Tex.	28° 30′	10-24-32	92	57.0	10.2	10.7	1928

TABLE III—*Continued*

Region	North Latitude	Approximate Emergence Date	Days to Seed Stalk Appearance	Mean Temperature (Degrees F)	Day Length		Remainder Index Sums (Day-Degrees)
					Minimum (Hrs)	Maximum (Hrs)	
			Nobel or Gaudry				
D. C.	39°	3-24-27	57	52.8	12.2	14.5	959
D. C.	39°	4- 8-28	50	56.4	12.9	14.7	1018
D. C.	39°	4-21-31	52	63.5	13.3	14.8	1431
D. C.	39°	4- 1-32	58	58.3	12.6	14.5	1293
D. C.	39°	5- 1-33	39	68.7	13.8	14.8	1276
D. C.	39°	4-19-34	45	63.0	13.3	14.8	1213
N. Y.	42° 30′	4-20-31	53	56.1	13.5	15.2	1064
N. Y.	42° 30′	5-10-32	39	61.7	13.4	15.3	1003
Calif.	38° 30′	1- 6-31	78	52.2	9.5	12.3	1263
Calif.	38° 30′	12-22-31	125	51.2	9.4	13.6	1905
Calif.	38° 30′	2- 8-33	77	63.8	10.4	13.6	1369
D. C.	39°	10-17-26	—	—	—	—	—
D. C.	39°	10-11-27	205	45.7	9.4	13.9	1989
D. C.	39°	10-13-31	—	—	—	—	—
Tex.	28° 30′	1- 8-31	—	—	—	—	—
Tex.	28° 30′	12-13-31	127	62.5	10.2	13.3	3364
Tex.	28° 30′	10-24-32	124	56.6	10.2	11.5	2550
			King of Denmark				
D. C.	39°	3-24-27	62	54.0	12.2	14.6	1119
D. C.	39°	4- 8-28	59	57.6	12.9	14.8	1274
D. C.	39°	4-21-31	55	64.0	13.3	14.9	1543
D. C.	39°	4- 1-32	63	58.9	12.6	14.8	1445
D. C.	39°	5- 1-33	43	70.1	13.8	14.9	1465
D. C.	39°	4-19-34	57	66.1	13.3	14.9	1715
N. Y.	42° 30′	4-20-31	69	58.9	13.5	15.3	1580
N. Y.	42° 30′	5-10-32	62	63.7	13.4	15.3	1717
Calif.	38° 30′	12-24-30	97	51.3	9.4	12.4	1482
Calif.	38° 30′	12-22-31	132	51.4	9.4	13.8	2035
Calif.	38° 30′	2- 8-33	80	54.0	10.4	13.7	1439
D. C.	39°	10-17-26	207	44.7	9.4	14.2	1803
D. C.	39°	10-11-27	218	46.5	9.4	14.3	2283
D. C.	39°	10-13-31	213	49.3	9.4	14.3	2830
Tex.	28° 30′	1- 8-31	111	58.2	10.4	13.2	2462
Tex.	28° 30′	12-13-31	127	62.5	10.2	12.9	3364
Tex.	28° 30′	10-24-32	132	56.6	10.2	11.7	2726

Standing Bloomsdale not shown in the table, behaved in a manner intermediate between Bloomsdale Savoy and Nobel or Gaudry. Viroflay responded very much like Bloomsdale Savoy, and Long Standing Bloomsdale was much like Nobel or Gaudry. Princess Juliana was intermediate between Nobel or Gaudry and King of Denmark.

A careful study of Table III shows but poor correlation between time of seed stalk appearance, temperature and day length among the several crops planted in the spring but between winter sown crops more definite relationships are evident. Although the California crops were started under a shorter day than the Texas crops they run into longer days and rather consistently shoot to seed sooner, with a markedly lower temperature accumulation and under a lower mean temperature. The crops near Washington, D. C. pass through a long period of cold during which no growth occurs and obviously are in a class to themselves. In the Texas and California crops the

earliest plantings usually required the longest time to shoot to seed but this was not always true.

Some factors other than day length and total heat appear to exert considerable influence in maintaining or terminating the vegetative stage of development of this plant. It might be supposed that the stage of plant development during which a given temperature prevails may be responsible for these irregularities in response to the factors under consideration. This position cannot be defended by the present data since there are wide differences in response to heat in apparently quite similar seasons; and on the other hand, many crops of some varieties have first shown seed stalks upon very similar total amounts of heat that have accumulated over seasons of entirely dissimilar heat distribution.

There are interesting differences in the coefficients of variation of time and heat summations of the several varieties as grown in the spring. Note that as the tendency to long standing increases among varieties, there is not only a *relative* decrease in variation in time to shoot to seed, but often an *absolute* decrease in difference between minimum and maximum time. With the exception of Virginia Savoy, all varieties show about the same degree of variation in heat accumulations up to shooting to seed. Thus even though Virginia Savoy is consistently the quickest seeder its behavior is the least predictable of the seven varieties. Considering relation to both time and temperature, Long Standing Bloomsdale is the most regular in behavior. The full significance of the differences in C. V. of time and temperature among the varieties cannot be determined without additional data.

The interrelationships of light, temperature, and apparently some unknown factor or factors are too complicated to be resolved by the limited data and simple methods attempted here. It is conceivable that soil and cultural conditions may play some part in determining the long-standing period of spinach but observations suggest that those factors have too little effect to account for the great differences occurring in the same field in different years. Unfortunately, the present study serves only to accentuate the lack of understanding of behavior of this crop rather than clearing up details of certain of its characteristics. Varietal studies made from other standpoints have already made clear the broad outlines or general features of behavior in response to the season.

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Effect of Size of Sets on Yield and on the Production of Doubles in Onions[1]

By H. C. THOMPSON, *Cornell University, Ithaca, N. Y.*

IN experiments conducted by the writer on premature seeding of onions, it has been observed that as the size of sets increases the percentage of seed-stalks and the percentage of doubles increase. Obviously, premature seeding and "doubling" affect the yield of marketable bulbs. The effect of size of set on marketable yield is complicated by the fact that storage temperature affects seed-stalk development, which, in turn, affects yield. In order to get some data on the effect of size of set on yield, the onions grown in the premature-seeding experiment in 1934 were sorted into grades, counted and weighed.

EFFECT OF SIZE OF SETS ON YIELD

Three varieties of onions, Ebenezer, Yellow Globe, and Red Wethersfield have been used for a number of years in the experiments on premature seeding and from these data were obtained on yield. The sets used were grown at Ithaca and after being cured in the field they were divided into several lots and stored at four different temperatures in cold storage and at one range of temperature in common storage. In the spring the sets were sorted into three sizes as follows: Large, 13/16 of an inch to 1⅛ inch in diameter; Medium, ⅝ to ¾ of an inch in diameter; and Small, ⅜ to ⅝ of an inch in diameter. All sets were planted 3 inches apart in the row with rows 18 inches apart. Planting was in quadruplicate with each row con-

TABLE I—YIELD OF MARKETABLE ONIONS GROWN FROM LARGE, MEDIUM, AND SMALL SETS STORED UNDER VARIOUS TEMPERATURES

Variety	Yield of Onions per 100 Feet of Row (Pounds)					
	30° F	32° F	40° F	50° F	60 to 70° F	Average
	Large (13/16 in. to 1⅛ in.)					
Ebenezer	79.75	83.87	24.19	33.00	66.19	57.40
Yellow Globe	99.44	81.00	13.87	19.56	65.37	55.85
Red Wethersfield	67.20	33.00	1.37	3.00	11.50	23.21
Average	82.13	65.96	13.14	18.52	47.69	45.49
	Medium (⅝ in to ¾ in.)					
Ebenezer	70.82	76.00	34.12	36.87	53.44	54.25
Yellow Globe	78.00	71.37	28.50	22.25	49.31	49.88
Red Wethersfield	60.56	53.44	8.69	7.19	14.00	28.77
Average	69.79	66.94	23.77	22.10	38.92	44.30
	Small (⅜ in. to ⅝ in.)					
Ebenezer	62.31	40.87	24.69	21.37	25.50	34.95
Yellow Globe	52.62	39.94	16.12	14.44	28.56	30.34
Red Wethersfield	42.87	45.44	7.25	2.25	15.00	22.56
Average	52.60	42.08	16.02	12.69	23.02	29.28

[1]Contribution No. 122 from Department of Vegetable Crops, Cornell University.

taining 100 sets. The data on yield of marketable bulbs are given in Table I.

The temperature under which the sets were stored had a marked effect on yield of marketable onions from all sizes of sets. In all cases the lowest temperature of storage (30 degrees F) was the best, and the yield was reduced as the storage temperature was raised from 30 to 32 and from 32 to 40 degrees F. The yield obtained from large sets stored at 50 degrees F was a little greater than from those stored at 40 degrees F. With medium and small sets the difference in yield between those stored at 40 and 50 degrees is small and probably not significant. The sets kept in common storage, held between 60 and 70 degrees F, produced a considerably larger yield than those held in cold storage at 40 or at 50 degrees F. At the highest temperature there was less seeding than at 40 or at 50 degrees F, and with the large sets this might account for the larger yield. With the medium and small sets this explanation does not hold for there was no appreciable number of seed-stalks developed at any of the three temperatures mentioned. There was less sprouting in common storage (60 to 70 degrees F) than in the 40- and 50-degree cold-storage rooms, probably because of lower humidity in the common storage. The sets in the common storage were more shriveled than those in any of the cold-storage rooms. Withering and drying in storage had a less depressing effect on subsequent yield of onions than did growth in storage. It should be noted, however, that many of the small sets in common storage were so badly shriveled that they were unfit for planting. Apparently, keeping the sets in a dormant or nearly dormant condition is desirable.

The yield of onions produced from small sets was much less than from either the medium or large sets in all comparisons except the one between large and small sets stored at 40 degrees F. In this case the yield from the large sets was reduced markedly by the large percentage of seed-stalks. Large sets stored at 30 degrees F produced a much larger yield than did either the medium- or small-size sets. If sets were stored at this temperature large ones might be more profitable than the medium-size or small ones. However, it would require about twice as many bushels of large as medium sets and four times as many bushels of large as small sets to plant a given area.

Effect of Size of Sets on Production of Doubles

In connection with the studies on premature seeding, data have been obtained on other factors that affect the yield of marketable onions. One of these factors is the tendency of the bulb to form doubles. During the 3 years, 1932 to 1934, data were obtained on the number and weight of doubles produced from sets that had been stored under the various temperatures previously mentioned. These data are given in Table II and consist of percentage of doubles for three varieties. The percentages represent the averages for all storage temperatures. The small sets produced no double onions.

Large sets produced on an average 20.79 per cent of double onions and the medium-size sets, 1.36 per cent. There was some difference between varieties in respect to the production of doubles and some

TABLE II—PERCENTAGE OF DOUBLE ONIONS PRODUCED FROM LARGE- AND MEDIUM-SIZE SETS OF THREE VARIETIES

Year	Percentage of Doubles			
	Ebenezer	Yellow Globe	Red Wethersfield	Average for 3 Varieties
Large ($\frac{13}{16}$ in. to 1⅛ in.)				
1932	13.35	22.19	11.25	15.71
1933	7.60	19.09	13.67	11.79
1934	38.55	25.05	16.60	26.73
Average for 3 years	24.65	23.38	14.18	20.79
Medium (⅝ in. to ¾ in.)				
1932	0.19	1.50	0.30	0.66
1933	1.02	6.48	2.88	2.33
1934	2.20	1.70	0.80	1.56
Average for 3 years	1.23	2.01	0.90	1.36

variation from season to season. Wilson (1), working with the Spanish type of onion grown from seed sown in the field, has shown that the production of double onions is influenced by the spacing given the plants in the row. As the distance was increased from 2 to 10 inches, by 2-inch intervals, the percentage of double onions increased. Thus, increasing the spacing has a somewhat similar effect on "doubling" as increasing the size of the sets. In both cases the food supply probably is the important factor. Large sets contain more stored food than small ones and wide spacing gives more favorable environment for growth and food storage than close spacing.

The temperature under which the sets are stored also affects the production of double onions, but this is complicated by the effect of temperature on subsequent development of the seed-stalk. When seed-stalks develop early the bulbs are less likely to split up than when the seed-stalks develop late. When we consider only those sets that did not produce seed-stalks, it is found that the percentage of doubles is smaller from sets stored at 30 than from similar sets stored at 40 or 50 degrees F. From this it appears that keeping the sets in a dormant condition during storage is desirable from the standpoint of reducing splitting, as well as for lessening seed-stalk development and increasing yield.

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The Effects of Certain Salts on the Growth of Onions[1]

By J. E. KNOTT, *Cornell University, Ithaca, N. Y.*

ONION growers who have applied copper sulfate to their muck soil for the purpose of improving the color and keeping quality of the bulbs claim that the tops are larger and stay green later in the season with increased yields resulting.

The experiments reported in this paper were designed to study the effect on bulb growth of the sulfate salts of copper and other metals next to it in the periodic table. The results were expected also to show whether the copper or the sulfate radical of the copper sulfate was responsible for the increased skin thickness and better color.

GREENHOUSE EXPERIMENTS

Muck soil which produced poorly-colored onions was placed in drums used in previous experiments (1933). Distilled water was supplied through the automatic watering device. A 3–12–18 fertilizer was mixed with the surface 8 inches of muck in each drum at the rate of 1,000 pounds to the acre before the first crop was planted. The second crop received no additional fertilizer. A half ton to the acre of a 5–10–5 analysis was applied for the third crop. $CoSO_4 . 7\ H_2O$; $CuSO_4 . 5\ H_2O$; $NiSO_4 . 7\ H_2O$; and $ZnSO_4 . 7\ H_2O$ were applied at the rate of 300 pounds to the acre with the fertilizer previous to the planting of the first crop. Each treatment was in triplicate. Ebenezer and Red Wethersfield sets grown at East Ithaca were used, 35 being planted in each drum. A photoperiod of 15 hours was provided by illumination with 100-watt lamps after sundown during the winter months to induce bulbing.

The average weight per bulb in grams of the mature bulbs grown under each treatment is given in Table I. In the first crop the zinc exerted a toxic effect. The copper did not increase the bulb weight over that of the onions on the check plots to which no copper sulfate

TABLE I—AVERAGE BULB WEIGHT OF ONIONS GROWN ON MUCK TREATED WITH 300 POUNDS PER ACRE OF VARIOUS SULFATES

Variety and Treatment	Crop of Oct. 8, 1932 to Apr. 19, 1933 (Gms)	Crop of May 2, 1933 to July 3, 1933 (Gms)	Crop of Sept. 27, 1933 to Apr. 18, 1934 (Gms)
Ebenezer			
Cobaltous sulfate	34.7±1.97	10.2±0.24	30.6±1.16
Zinc sulfate	27.8±1.31	12.5±0.32	32.7±1.28
Nickel sulfate	32.7±1.68	13.6±0.34	38.4±1.32
Copper sulfate	40.9±1.86	15.6±0.38	34.9±1.29
No sulfate added	36.3±1.60	11.9±0.30	34.9±1.48
Red Wethersfield			
Copper sulfate	38.2±1.77	13.2±0.35	33.6±1.22
No sulfate added	32.4±1.48	12.1±0.26	29.8±0.99

[1]Contribution No. 124 from Department of Vegetable Crops, Cornell University.

was added. It did however produce significantly larger bulbs than the nickel or the zinc. The copper application resulted in larger Ebenezer bulbs in the second crop than on the mucks receiving the other sulfates or on that to which no sulfate was applied. The premature ripening of the bulbs in the second experiment due to late planting and the high temperature in the greenhouse may have been a factor in this single instance where the copper increased the bulb weight. The copper treatment did not increase the size of the Red Wethersfield onions significantly in any of the experiments.

The weight of the Ebenezer bulbs in the third experiment was not increased by copper. The nickel treatment gave heavier bulbs than cobalt in the second experiment and better than zinc or cobalt in the third.

The measurements of the thickness of the first complete dry scale are presented in Table II. Copper sulfate was the only salt that increased the thickness and the color of the scales; in fact the scales on the bulbs grown with cobalt, nickel and zinc are thinner than on the check in the second and third crops. These data indicate that it is the copper and not the sulfate of the copper sulfate that is responsible for the thicker, better-colored scales. The scales of the Red Wethersfield bulbs were thicker and had a somewhat darker purple color on the muck receiving copper than on the untreated muck.

TABLE II—AVERAGE THICKNESS OF FIRST COMPLETE OUTER DRY SCALE

Variety and Treatment	Crop of Oct. 8, 1932 to April 19, 1933 (Mm)	Crop of May 2, 1933 to July 3, 1933 (Mm)	Crop of Sept. 27, 1933 to April 18, 1934 (Mm)
Ebenezer			
Cobaltous sulfate	.017±.0004	.013±.0003	.014±.0004
Zinc sulfate	.017±.0003	.013±.0004	.014±.0004
Nickel sulfate	.018±.0004	.013±.0003	.014±.0003
Copper sulfate	.029±.0006	.025±.0004	.029±.0006
No sulfate added	.018±.0004	.017±.0004	.017±.0003
Red Wethersfield			
Copper sulfate	.030±.0018	.028±.0004	.030±.0005
No sulfate added	.016±.0003	.015±.0003	.017±.0004

FIELD EXPERIMENTS

The effect of copper sulfate on yield was studied in growers' fields in 1933 and 1934. The rate of application was 300 pounds to the acre. The plots were 1 rod square. The six replications of the treated and untreated plots were arranged in checkerboard fashion with a 2-foot cropped area between plots at right angles with the rows. At harvest the two outside rows on each plot and a one-foot strip at each end were dropped. Individual row records were taken on ten rows 14½ feet long in each plot. In the first and third experiments seed of the Orange County Danvers variety was used. Ebenezer sets were planted in the second experiment and Yellow Globe Danvers seed in the fourth.

The onions on the plots receiving copper sulfate had larger tops, and ripened down a little later than on the untreated plots. In all cases the copper resulted in firmer bulbs with thicker, better-colored scales. The yield data are given in Table III. Although differences in yield of 21 to 38 bushels out of a total yield of approximately 500 bushels to the acre were obtained, only that in the third experiment closely approached the commonly accepted level of significance.

TABLE III—THE EFFECT OF COPPER SULFATE ON THE YIELD OF ONIONS IN FIELD PLOTS

Year of Experiment	Cooperator	Average Pounds of Onions to a 14½-foot Row: 300 Pounds of Copper Sulfate per Acre	Average Pounds of Onions to a 14½-foot Row: No Copper Sulfate
1933	J. Slevenski	12.0±0.26	11.1±0.28
1933	C. Russo	11.9±0.15	11.4±0.16
1934	P. Mudrick	12.7±0.19	12.1±0.15
1934	J. Hucko	15.1±0.21	15.1±0.20

DISCUSSION

Stimulation of crops by applications of copper has been claimed by a number of investigators. The experiments reported here do not indicate that onion yields are greater when copper is applied. Instances have been observed where the copper sulfate had been spread on part of a field, and the onions on that part stayed green while on the remainder the tops ripened prematurely through disease. Possibly the greater vigor of the tops imparted by the copper had lessened the susceptibility to the parasite. In those cases a difference in yield might well be expected, but it could not be said to have been produced by a stimulation of growth by the copper sulfate.

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Root Development of Beans, Cabbage and Tomatoes as Affected by Fertilizer Placement[1]

By Charles B. Sayre, *Experiment Station, Geneva, N. Y.*

In connection with a field experiment at Geneva in 1934 comparing the effectiveness of fertilizer placed at various depths and distances from the plants, studies were made of the effect of the fertilizer on the root systems of different crops. It was the author's expectation that stimulated root development would be found in the soil surrounding the fertilizer band and probably would be greatest below the band. He was surprised to find that with each of the crops studied there was an extraordinary development of fine fibrous feeding roots right in the fertilizer bands.

Wherever the fertilizer bands were placed, as soon as the roots encountered the band, the character of the root growth changed and there were developed very fine many-branched feeding roots that tended to completely permeate the fertilizer bands.

Fig 1. Showing concentration of fine fibrous roots in the fertilizer band in contrast to the longer less branching roots elsewhere.

With beans this is illustrated in Fig. 1, which shows the concentration of fine fibrous roots in the fertilizer band and the contrasting character of the roots which did not encounter the fertilizer. In the

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latter case the roots were larger and longer and had fewer branched feeding roots. In the case illustrated, a single continuous band of 4–16–4 fertilizer was applied 2½ inches to the side and 1 inch below the seed. The fertilizer was used at the rate of 300 pounds per acre.

In Fig. 2 the plant at the left received this same treatment. The large mass of fibrous roots was in the fertilizer band. The plant at the right in Fig. 2 was taken from a plat in which the fertilizer was applied at the rate of 300 pounds per acre in a broad band 2 inches directly below the seed. A dense mass of finely branched feeding roots developed on all the roots which grew downward into the fertilizer band while the roots which grew out to the sides and missed the fertilizer did not develop the masses of fine feeding roots. These photographs were taken 25 days after the beans had been planted.

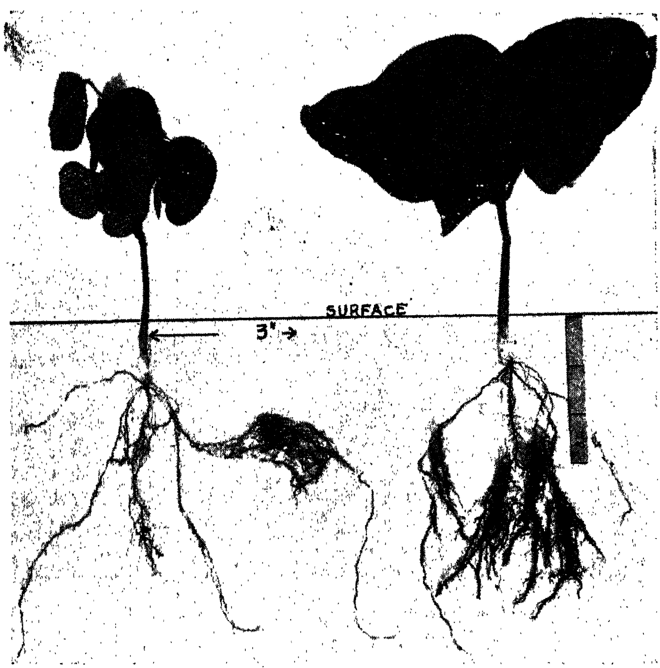

FIG. 2. Typical root development in fertilizer bands. (Left) Single band 2½ inches to one side. (Right) Broad band 2 inches directly below the seed.

In Fig. 3 is shown the characteristic root development of cabbage plants when the roots encountered fertilizer bands. In this case 600 pounds per acre of 4–16–4 fertilizer was applied in bands on each side of the row 2 inches away from the plant and 5 inches below the surface of the soil. The cabbage plant normally makes an exceedingly extensive root development, with many large branching secondary

roots that cover a very extensive feeding area (5). A number of different placements were compared, that is, single bands and double bands at various depths and distances. Wherever the cabbage roots encountered a fertilizer band the character of the root growth changed. The roots became more fibrous and finely branched and tended to follow along the fertilizer band and fill it completely. In Fig. 3 the large indistinct knob in the lower center foreground is a mass of the roots showing how densely they filled the fertilizer band. Above and to the left of this can be seen the roots in the other fertilizer band. In this case the roots were disentangled somewhat to show that they are growing right in the fertilizer itself. This photograph was taken 24 days after the cabbage had been transplanted to the field. The fertilizer was applied with an attachment to the transplanting machine.

FIG. 3. Showing development of fibrous roots in fertilizer bands on each side of cabbage row.

In Fig. 4 is shown the typical growth of tomato roots where they encountered fertilizer bands and the characteristic growth where they did not come in contact with the fertilizer. The tomato plant normally makes a large number of primary branching roots which cover a very wide feeding area (5). The plant shown in Fig. 4 was fertilized at the rate of 600 pounds per acre of 4–16–4. The fertilizer was applied with an attachment to the transplanting machine that distributed the fertilizer in 2 parallel bands 4 inches away from the plant on each side. When the tomato roots reached the fertilizer bands they developed a very dense fibrous mass of roots right in the fer-

tilizer. The plant shown in Fig. 4 was photographed 45 days after transplanting. The fertilizer bands were so completely filled with densely intertwined roots that long strands would hold together when removed from the soil. Similar results with corn were reported by Millar (2).

It is a well known fact that the germination of bean seeds may be seriously delayed or the seedlings killed by fertilizer placed too close to the seeds. Observations were made of the developing seedlings. It was found that the roots develop rapidly diagonally downward and less rapidly to the side. In the field experiment it required 8 days from the time the seeds were sown until the seedlings appeared above ground. Nine days after sowing, the roots of the seedlings were examined and it was found that the roots had not yet reached fertilizer bands placed 2½ inches to one side and 1 inch below the

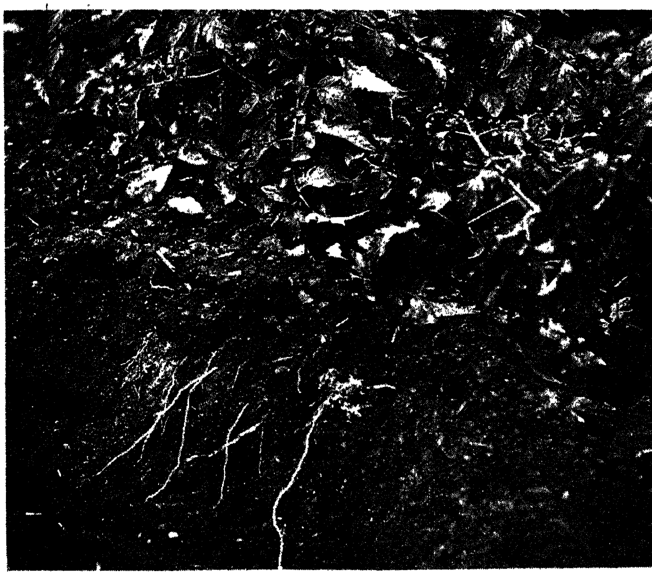

FIG. 4. Typical roots of tomato showing concentration of fibrous roots in fertilizer bands on each side of plant.

seed level. At the same time in another plat where the fertilizer was placed 2 inches directly below the seed the roots had penetrated the fertilizer band and showed no sign of injury. Ten days after sowing, the roots reached the fertilizer in the side placements. Thirteen days after seeding there was a marked development of fine fibrous roots in the fertilizer bands. It was clearly evident that after a certain length of time in the soil this 4–16–4 fertilizer made an especially favorable media for the development of fibrous roots of the three crops studied, and this was accompanied by great stimulation in the growth of the plant.

Since fertilizer is injurious to roots and to seeds when first applied it was evident that important changes had taken place in the fertilizer within a few days after being applied to the soil. Accordingly a new experiment was laid out in the greenhouse to study what changes take place in the fertilizer band in the soil and how long a time is required for the fertilizer to lose its injurious properties.

For this experiment fertilizer bands 1⅞ inches wide were placed in the soil. The rates of application were equivalent to that applied in bands for rows 30 inches apart at the rates of 600 pounds, and 75 pounds per acre. A commercial 4–16–4 fertilizer was used. According to the guaranteed analysis this fertilizer contained the following ingredients per ton: 100 pounds nitrate of soda, 100 pounds garbage tankage, 100 pounds ammonium sulphate, 165 pounds Ammo-Phos A, 1375 pounds ammoniated superphosphate, and 160 pounds muriate of potash. The fertilizer bands were covered with narrow strips of cheesecloth and 1 inch of soil was then filled in uniformly over the entire area. These cheesecloth covers over the fertilizer bands did not interfere with the capillary movement of the soil solution, but did permit cleanly uncovering the fertilizer bands for recovery for analysis and for planting seed directly in the band.

After the soil was filled in over the fertilizer bands the entire bench was watered to settle the soil and establish capillary action. The watering was at the rate approximately equivalent to ¼ inch of rainfall. A similar watering was given after 6 days and again after 12 days to provide favorable moisture conditions for the germination of the seeds.

Bean seeds were sown (A) ½ inch to one side of the fertilizer bands, (B) directly down the center of the bands, and (C) 2½ inches to the side of the band. Bean seedlings, two weeks old, sprouted in sand were also transplanted at the same distances in relation to the bands. At successive 2-day intervals the fertilizer bands were uncovered and seeds sown and seedlings transplanted as indicated above. At the same time fertilizer was recovered from bands in the soil for analysis.

Seedlings were transplanted to the fertilizer bands at three periods, namely, (A) at the time the fertilizer was applied, (B) 2 days after, and (C) 4 days after the fertilizer was applied. Twenty seedlings were transplanted in each row. The percentage of seedlings that survived the transplanting is shown in Table I.

TABLE I—EFFECT OF FERTILIZER ON TRANSPLANTED BEANS (600 POUNDS PER ACRE 4–16–4 IN BANDS)

Position of Plants	Days Between Fertilizer Application and Transplanting		
	0	2	4
	Per cent of plants Surviving		
Set ½ in. away from fertilizer	100	100	100
Set in center of fertilizer band	0	30	100
Set 2½ in. from fertilizer	100	100	100

The seedlings that perished appeared to have died as a result of plasmolysis. Similar results with fruit trees were reported by Tukey (4). The fine roots were shriveled and all the tissues were wilted or collapsed. Apparently this was caused by too great a concentration of soluble salts from the fertilizer. Skinner (3) states that the soluble salt concentration in the soil solution is tremendously increased in the areas where readily soluble fertilizers such as sodium nitrate and potash salts are used, and this excessive soluble salt concentration may kill plants. Coe (1) reports that greatest injury occurs when more soluble chemical fertilizers are used. The fact that, after the fertilizer had been in the soil 4 days, seedlings could be transplanted directly into the fertilizer band without injury showed that the soluble salt concentration had been greatly reduced in the fertilizer band. This is corroborated by the analyses of the fertilizer recovered from the soil. (Table III.)

Seeds were sown in the fertilizer bands at 2-day intervals covering a period of 12 days from the time the fertilizer was applied. Twenty seeds were sown in each row and the percentage of germination is given in Table II. The soil used in this experiment was first sterilized so that soil-borne disease organisms would not be a factor in affecting the germination of the seeds.

TABLE II—GERMINATION OF BEANS PLANTED IN FERTILIZER AT SUCCESSIVE INTERVALS

Position of Seed	Days from Fertilizer Application to Planting						
	0	2	4	6	8	10	12
Fertilizer at rate of 600 pounds 4–16–4 per A.							
	Per cent stand						
½ in. away from fertilizer	90	85	95	70	80	70	75
In center of fertilizer band	0	10	35	55	75	65	75
2½ in. away from fertilizer	95	95	85	90	90	90	80
Fertilizer at rate of 75 pounds 4–16–4 per A.							
	Per cent stand						
½ in. away from fertilizer	100	95	80	95	80	70	85
In center of fertilizer band	80	85	85	70	70	90	70
2½ in. away from fertilizer	95	80	70	85	95	90	85

From Tables I and II it is evident that there is very little horizontal movement of the soluble salts from the fertilizer band because seeds and seedlings planted ½ inch away from the band received no injurious effect. This agrees with observations by Coe (1).

It should be noted that at the rate of 75 pounds per acre the fertilizer only slightly reduced the germination of seeds planted directly in the band. Evidently the soluble salt concentration in the soil solution from this rate of application was not sufficient to cause serious plasmolysis or injury to the seedlings.

TABLE III—ANALYSIS OF 4-16-4 FERTILIZER RECOVERED FROM SOIL AT SUCCESSIVE INTERVALS*

	No. of Days in the Soil					
	0	2	4	6	8	12
NH_3 nitrogen (per cent).....	3.34	0.51	0.19	0.19	0.17	0.07
NO_3 nitrogen (per cent).....	0.83	0.19	0.08	0.10	0.07	0.08
Organic nitrogen (per cent)..	0.52	0.63	0.76	0.75	0.81	0.69
Available P_2O_5 (per cent) ...	17.00	11.72	10.87	11.09	10.71	10.60
Insoluble P_2O_5 (per cent)....	0.45	0.96	1.24	1.13	1.26	1.08
K_2O (per cent)............	5.33	1.86	0.64	0.38	0.38	0.22
Net balance in pounds of $CaCO_3$ per ton...........	—303	—14.5	+26.3	——	——	+46.5

*The author desires to express his appreciation to Messrs A. W. Clark, F. J. Kokoski, C. O. Willets and E. Cooper Smith of the Fertilizer Control Laboratory, Chemistry Division, who made all of the fertilizer analyses.

From Table III it will be seen that the soluble salts in the fertilizer band diffuse rapidly into the soil solution. The rapidity of loss of ammonia and nitrate nitrogen and of potash salts is very striking. In 2 days 5/6 of the inorganic nitrogen and 2/3 of the potash had diffused into the soil solution. After 4 days in the soil less than 1/15 of the inorganic nitrogen and ⅛ of the potash remained in the fertilizer band. This readily explains why the fertilizer quickly loses its injurious effect on seeds or seedlings. After 4 days in the soil the changes in the composition of the fertilizer, that is, the loss of soluble salts, was at a greatly reduced rate.

About ¼ of the phosphoric acid in the fertilizer diffused into the soil solution in the first 2 days in the soil. After that the phosphorus was lost very slowly. It would appear from the figures in Table III that the insoluble P_2O_5 and also the organic nitrogen in the fertilizer increased during the first 4 days in the soil. Obviously the actual amount of these elements did not increase, but the proportion of these insoluble substances increased in the residue because of the greater loss of the other ingredients.

It is interesting to note the changes in the acid-base balance after the fertilizer was placed in the soil which had a pH of 6.9. Originally the fertilizer required 303 pounds of $CaCO_3$ per ton to correct the acidity. After 2 days in the soil only 14½ pounds per ton would be needed to neutralize the acidity of the fertilizer band. After 4 days in the soil, the residual fertilizer was alkaline and this alkaline balance increased after 12 days. This change in the reaction of the fertilizer was evidently due to the more soluble ingredients being acid and the less soluble residue being alkaline.

Rate of movement of the soluble salts from fertilizer undoubtedly will be greatly influenced by the relative soil moisture content. It should be noted that these field results were obtained in an abnormally dry season.

In the entire month of May we had a rainfall of only 0.41 inches, all of which came before May 22. The tomatoes were set in the field May 26 and received no water until June 10, when there was a rainfall of 1.27 inches.

The beans were planted June 14 and the cabbage was transplanted June 15. The photographs shown in Figs. 1 to 4 were taken July 11. The rainfall received by the beans and cabbage from the time they were planted in the field until photographs were taken was, June 19, 0.70 inch; July 6, 0.50 inch; July 7, 0.10 inch; and July 8, 0.02 inch. It is plainly evident that there was not sufficient rainfall to cause any loss of soluble fertilizer salts from leaching and that the soil moisture was low throughout.

Undoubtedly the rate of diffusion or movement of soluble salts from the fertilizer will depend to a marked extent upon the percentage saturation of the soil.

In the greenhouse tests the moisture content of the soil was favorable for more rapid movement of the soluble materials from the fertilizer band into the soil solution. However, there was no excessive watering and no leaching away of soluble salts in the greenhouse test.

In conclusion, it is evident that a "complete" commercial fertilizer is injurious to seeds and plants because of the excessive concentration of soluble salts particularly of nitrogen and potash, when first applied. Since movement of the soil solution is principally down and up, depending upon rainfall and surface evaporation respectively, the soluble salt concentration is likely to be excessive immediately below or above the fertilizer for a period of a few days. Fertilizer placed below the seed or plant should therefore be at sufficient depth so that the soluble salt concentration will be reduced before the roots reach it. There is very little horizontal movement of soluble salts in the soil solution. Consequently fertilizer placed to the side of seeds or plants at sufficient distance (½ inch to 2½ inches away) so that the roots will not reach the fertilizer for a few days will have no injurious effect. In any placement the fertilizer should be far enough away from the seed or plant so that the developing roots will escape the excessive soluble salt concentration in and immediately above or below the fertilizer band for a few days. These salts diffuse rapidly into the soil solution and the excessive concentration of soluble salts in the fertilizer band is thus reduced. Following this the fertilizer becomes an excellent media for root development. Roots coming in contact with it then will develop an unusual number of fine fibrous feeding roots right in the fertilizer band, and this will be accompanied by stimulated plant growth.

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Some Soil Conditions Affecting Lettuce Seed Germination

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THE studies outlined in this paper were suggested by an extremely wide variation in germination noted between various samples of lettuce seed from the same stock and under similar conditions except for the kind of soil used. The general uniformity of all other conditions under which the various samples were grown indicated that some soil factor must be responsible for much of the variation.

Two general types of soil were used for the plantings in which the variation was first noted. One of these consisted of soil from a compost pile which had been formed from 1/3 Kankakee muck from South Bend, Indiana, and 2/3 of a medium loam soil from Arlington County, Virginia, which contained a small amount of manure. The other soil consisted largely of fine river sand with a small amount of the loam soil used in the above-mentioned compost. In nearly every case, samples of seed from the same stock gave much lower germination when planted in the muck-compost soil.

To study the influence soil might have on the germination of lettuce seed, a series of plantings designated as "Series 1" was made in planting flats 1 foot wide and 2 feet long. The flats were divided into four sections, each section of each flat being filled with a different type of soil. The following soils were used:

1. Muck obtained from South Bend, Indiana.
2. River sand passed through a screen of 12 meshes to the inch.
3. A medium loam soil from Arlington County, Virginia.
4. A mixture consisting of 1/3 Indiana muck and 2/3 of a loam compost containing a small amount of decomposed manure.

Twelve flats were filled, distributing the different soils at random as to position in the flat. Fifty seeds were planted in each section and regularly spaced to facilitate the counting of the seedlings. The seeds were covered to a depth of approximately 3/16 inch. The depth was determined by measuring the volume of soil applied to a given area of surface.

After covering the seed with soil of the kind in which it was planted, each flat was thoroughly watered from the surface by means of a sprinkling can having a fine nozzle. The flats were placed on a greenhouse bench where the day temperature averaged between 75 and 80 degrees F and the night temperature from 60 to 65 degrees.

The number of days required for emergence of the first seedlings varied somewhat and the period from the first emergence to the time the last plants appeared was even more variable. Generally, most of the seedlings had emerged by the seventh or eighth day after planting. The emergence counts made on the tenth day after planting were used in compiling the tables for statistical analysis.

In order to compare the behavior of different varieties of lettuce under different soil conditions, this series was repeated twice using a different variety in each case. The three varieties used were Iceberg,

Unrivalled, and a hybrid selection Number 931. The seed used was 1934 stock harvested in July. Analysis of the variance of the three varieties in the four different soils is given in Table I.

TABLE I—ANALYSIS OF VARIANCE IN GERMINATION OF THREE VARIETIES OF LETTUCE IN FOUR TYPES OF SOIL

Variety	Due to—	Degrees of Freedom	Sum of Squares	Mean Square	½ Log e Mean Square	Observed Value for z			Value Which z May Exceed in 5 Per cent of Trials
						n_1	n_2		
Iceberg	Flats	11	556.02	50.55	.8101	3	11	2.2204	.6387
	Soils	3	12864.35	4288.12	3.0305	11	33	.1610	.3777
	Error	33	1208.90	36.63	.6491	3	33	2.3814	.5333
	Total	47	14629.27						
Unrivalled	Flats	11	321.5	39.23	.5363	3	11	2.3427	.6387
	Soils	3	9502.5	3167.50	2.8790	33	11	.1399	.4387
	Error	33	1277.0	38.67	.6762	3	33	2.2028	.5333
	Total	47	11101.0						
Hybrid No. 931	Flats	11	357.0	32.45	.5885	3	11	2.3305	.6387
	Soils	3	10294.5	3431.50	2.9190	33	11	.0820	.4387
	Error	33	1261.5	38.23	.6705	3	33	2.2485	.5333
	Total	47	12067.27						

From the last two columns of Table I it can be seen that variation in germination due to soil is significant for each of the three varieties tested. The final results are presented in tabular form in Table II.

TABLE II—SUMMARY OF RESULTS OF GERMINATION TESTS OF THREE VARIETIES OF LETTUCE IN FOUR TYPES OF SOIL

Germination	Variety	Muck	Sand	Loam	Muck Compost	Mean	Standard Error	Error of a Difference
Number of plants from 600 seeds 10 days after planting	Iceberg	579	524	246	102	362.75	25.67	36.30
	Unrivalled	585	546	267	198	399.00	26.38	37.30
	Hybrid No. 931	588	559	400	145	423.00	26.23	37.09
Germination in percentage	Iceberg	96.50	87.33	41.00	17.00			
	Unrivalled	97.50	91.00	44.50	33.00			
	Hybrid No. 931	98.00	93.17	66.67	24.17			
Coefficient of variability	Iceberg	3.40	24.74	52.39	50.94			
	Unrivalled	2.39	8.20	37.12	42.73			
	Hybrid No. 931	1.86	4.50	24.75	65.25			

The variation in germination followed the same trend in each variety. Muck gave the highest percentage with 96.50 for Iceberg, 97.50 for Unrivalled, and 98.00 for hybrid No. 931. The percentage of germination in river sand was only slightly lower than in muck with 87.33 for Iceberg, 91.00 for Unrivalled, and 93.17 for hybrid No. 931. Both the loam and compost soils gave poor germination. The

percentages in loam were 41.00 for Iceberg, 44.50 for Unrivalled, and 66.67 for hybrid No. 931. The muck compost was a poor fourth with 17.00 per cent for Iceberg, 33.00 per cent for Unrivalled, and 24.17 per cent for hybrid No. 931.

The significance of differences in germination between the different soils can be readily determined by comparing the difference with the error of a difference given in the last column of Table II. Differences in germination between muck and sand were insignificant in every case. The differences between muck-compost and loam and between muck-compost and sand were significant in every case except for Unrivalled, which gave no significant difference between muck-compost and loam.

The germination counts made in Series 1 showed that much greater variation between different flats of the same soil occurred in the compost and loam than in the sand and muck soils. These soils also gave the lowest percentage of germination. The variation between lots of the same soil in different flats was greatest in the muck compost and least in the muck. This variation between different lots of the same soil is shown by the coefficients of variability. The coefficients were as follows: In muck, 3.4 for Iceberg, 2.39 for Unrivalled, and 1.86 for hybrid No. 931. In sand, 24.74 for Iceberg, 8.20 for Unrivalled, and 4.50 for hybrid No. 931. In loam, 52.39 for Iceberg, 37.12 for Unrivalled, and 24.75 for hybrid No. 931. In muck compost, 50.94 for Iceberg, 42.73 for Unrivalled, and 65.23 for hybrid No. 931. Since an effort had been made to have all conditions other than soil as nearly uniform as possible, it was difficult to explain the great variability between flats of compost and loam in view of the low variability between flats of muck and sand. Differences in amount and method of watering of the flats appeared to be the most likely to causes of variation between flats of the same soil.

A second series, designated as "Series 2", was set up to determine what effect the method of watering might have on variation between flats. Two types of soil were used: (A) Indiana muck, (B) muck compost of the composition used in Series 1. This soil was passed through a screen of ten meshes to the inch.

To this series was added an additional factor, namely, the influence of the soaking the seed on germination. Eight flats were filled with each type of soil. Each flat was divided into eight sections. Fifty dry seeds of hybrid No. 931 were planted in four sections of each flat. In the remaining four sections of each flat, 50 seeds of hybrid No. 931 which had been soaked in tap water for 3 hours, were planted. The four plantings of each lot of seed were distributed so that dry and soaked seed fell both at the ends and in the middle of each flat. The soaked seed were dried off on blotter paper before planting. The seed were covered to a depth of approximately 3/16 inch. Half of the flats containing muck, and half of the flats filled with muck-compost, were placed in water in galvanized iron vats long enough to permit the soil to take up enough water to thoroughly wet the surface soil within 15 minutes after their removal from the water.

TABLE III—ANALYSIS OF VARIANCE IN GERMINATION OF SOAKED AND DRY LETTUCE SEED IN TWO TYPES OF SOIL, SUB- AND SURFACE-IRRIGATED

Soils	Due to—	Degrees of Freedom	Sum of Squares	Mean Square	½ Log e Mean	Observed Value for z n_1	n_2		Value Which z May Exceed in 5 Per cent of Trials
Muck	Groups	7	18.38	2.63	.4835	7	3	.0254	1.0926
	Treatments	3	7.50	2.50	.4581	3	21	.0800	.5612
	Error	21	44.75	2.13	.3781	7	21	.1054	.4572
	Total	31	70.63						
Muck Compost	Groups	7	69.023	9.860	1.144	3	7	2.373	.7347
	Treatments	3	3404.148	1134.716	3.517	21	7	0.048	.6182
	Error	21	227.602	10.838	1.192	3	21	2.325	.5612
	Total	31	3700.773						

The remaining flats of each kind of soil were surface-watered with a sprinkling can, as in Series 1. The germination counts made on the tenth day after planting were used in formulating the tables.

The analysis of variance in germination between the different soils and treatments is presented in Table III. Comparison of the last two columns of Table III show that treatments were clearly significant in the compost soil, while treatments gave no significant difference in germination in the Indiana muck. The final results of Series 2 are summarized in Table IV.

TABLE IV—SUMMARY OF RESULTS OF GERMINATION OF DRY AND SOAKED LETTUCE SEED IN SUB- AND SURFACE-IRRIGATED SOILS

Germination	Soil	Dry Seed Sub-irrigated	Soaked Seed Sub-irrigated	Soaked Seed Surface-irrigated	Dry Seed Surface-irrigated	Mean	Standard Error	Standard Error of Difference
Number of plants from 400 seeds 10 days after planting	Muck Compost	383	379	320	179	315.30	9.3	13.15
	Muck	385	391	381	386	385.75	5.1	7.21
Germination (Per cent)	Muck Compost	95.80	94.80	80.00	44.75			
	Muck	96.30	97.80	95.40	96.50			

Comparisons of differences in germination with standard error of a difference given in the last column of Table IV show that both dry seed and soaked seed in sub-irrigated flats gave a significantly higher germination than either dry seed or soaked seed in surface-irrigated flats of muck compost. Soaked seed surface-irrigated in this soil gave a significant increase over dry seed surface-irrigated. However, there was no significant difference between dry seed sub-irrigated

and soaked seed sub-irrigated in muck compost. No significant differences were found between any of the treatments in muck.

Discussion

The results of these two series of tests indicate that the germination of lettuce seed is greatly influenced by conditions of the soil medium. The percentage of germination declines with conditions which reduced soil aeration. Germination was reduced to zero in tests not included in this paper in which very finely screened soils were used. Germination varied from one hundred per cent in some plantings in Indiana muck, to zero in compost soil screened through a forty meshes to the inch screen. Depth of covering was varied from approximately 1/16 to ¼ inch without significant difference in germination, except in very fine soils.

Series 2 gave some very interesting results. Soaking of seed and method of irrigation gave no significant differences in germination in the well-aerated muck. The difference in germination between soaked and dry seed was not significant in sub-irrigated muck-compost. It is interesting to note, however, that both soaked and dry seed gave significant differences in favor of sub-irrigation between sub- and surface-irrigation and that the difference between soaked and dry seed was significant in favor of soaked seed when this soil was surface-irrigated.

The data presented, while not proving the point, indicate that lettuce seed has a high oxygen requirement for germination and that fine soils and soils which have been puddled on the surface when wet after planting, are unable to supply sufficient oxygen for germination. It is recognized that wide variation may exist in the same type of soil under various conditions. Muck and sandy soils, especially course sand, are not likely to vary greatly in texture. Soils of fine texture, such as clays and loams, which consist largely of aggregates of small particles, vary greatly in their aeration under various conditions. The more the aggregates are broken down, the poorer the ventilation. The addition of water to the surface, especially in the form of dashing rains, greatly reduce the size of soil aggregates at the surface resulting in a film of fine particles which lower the gas exchange between the seed and the air above and consequently would be expected to cause greater variation than sub-irrigation.

If the failure of lettuce seed to germinate under certain soil conditions is due to insufficient oxygen supply, the stimulation of germination in such soils by soaking the seed may be due to lower oxygen requirement resulting from the soaking. Soaked seed which had been dried for several days after soaking did not give the response under adverse soil conditions as did soaked seed planted after surface drying only. Soaking appears to initiate the process of germination and to lower the oxygen requirement permitting the process to continue under conditions of oxygen supply too low for its initiation. It is believed that at least part of the so-called dormancy in lettuce seed is due to some seed having a rather high oxygen requirement for germination, and that under certain conditions, the oxygen supply in

the soil is too low for germination of such seed. The writer recognizes that such an explanation is more or less speculative, but it seems probable from the results obtained. Further study of the oxygen requirement of lettuce seed is contemplated and may throw additional light on the question of the cause of poor germination under certain soil conditions.

The question may be asked whether the seed which have not emerged in ten days after planting will not germinate later. Some of them will, and in some cases perhaps most of them. However, these studies indicate that seed which fail to germinate within 10 days are very slow to germinate, are irregular in emergence, and under such conditions are likely to result in an irregular stand of weak plants varying greatly in size in later stages of growth, and producing an uneven appearance.

Conclusions

The germination of lettuce seed is greatly influenced by soil conditions. Much lower and slower germination may result in fine, poorly-aerated soils than in coarse, well-aerated soils. Surface-irrigation of soils which have a tendency to puddle checks the rate and reduces the percentage of germination. Sub-irrigation of soils which have a tendency to puddle gives a higher percentage of germination than surface-irrigation of such soils. Soaking of seed in water for a period of 2 or 3 hours before planting gives a significant increase in germination in poorly-aerated soils but has little influence on germination in well-aerated soils. Planting of lettuce seed in soils which have a tendency to puddle when wet should follow, rather than precede, a rain.

Cellophane[1] and Waxed Paper Wrappers for Storing Cucumbers

By Leslie R. Hawthorn, *Texas Agricultural Experiment Station, Winter Haven, Tex.*

CUCUMBERS harvested during the warm dry weather of late May and June in southwest Texas deteriorate fairly rapidly if left unwrapped and exposed to ordinary room conditions. Brown in 1928 working with various vegetables and fruits found the type of wrapper used had considerable effect on the loss in weight (2). More recently in tests in Georgia with asparagus and in Florida with citrus certain moistureproof films of cellulose have materially reduced loss of weight in storage (1, 3, 4). These cellulose films are also becoming increasingly popular as attractive mediums in which to market various fruits and vegetables (5). In 1933 a preliminary experiment in wrapping cucumbers in various grades of Cellophane was conducted. In 1934 the test was repeated, with additional treatments.

Materials and Methods

Marketable fruits harvested from a varietal trial of cucumbers were used in 1933. To minimize the effect of variety each sort used was distributed equally through all treatments. These consisted of: (A) Unwrapped (check), (B) plain transparent or P. T. Cellophane, (C) an intermediate grade of S. S. T. Cellophane, and (D) moistureproof or M. T. Cellophane. Twenty-five fruits were placed in each treatment within a few hours after harvest. In the Cellophane treatments each fruit was tightly wrapped in an 8 by 10 inch sheet of Cellophane which was then firmly twisted at the ends. The fruits were in no sense sealed in the Cellophane, as there was usually an air passage where the edges of the wrapper overlapped.

Each fruit after being wrapped was weighed to the nearest tenth of a gram. Whenever the daily weighings showed that a fruit had lost 15 per cent of its original weight, it was removed from storage, as on the basis of the unwrapped treatment, fruits were on the average unfit for use when they reached this weight. All the cucumbers were stored on open shelves in the Station laboratory. While no daily temperature readings were made within the storage room, official temperature and weather records taken in the vicinity of the laboratory were available. The mean daily temperature ranged around 84 to 88 degrees F with a mean maximum of 97 to more than 100 degrees F. Observations on several occasions indicated that indoor temperatures were usually 5 to 6 degrees lower. During the period of the tests doors and windows were open during all the daylight hours allowing of free circulation of air.

The procedure in 1934 was essentially the same as that in 1933, except that only two varieties of cucumbers were used. Most of the fruits were Early Fortune, but a few of Kirby Stays Green were also included. Both varieties were equally distributed between all treatments.

[1]Cellophane is the registered trade name of the cellulose film made by the Du Pont Cellophane Co., who furnished the Cellophanes used in these tests.

Two additional treatments were added to the experiment making six in all. One was another grade of intermediate (S. A. T.) Cellophane, and the other was a waxed (paraffined) paper commonly used in wrapping bread.

Since some fruits have a decided lack of turgidity when they have lost 15 per cent of their weight, a record was kept to determine when they had lost only 10 per cent. All were still maintained in storage however until they had lost 15 per cent.

Under the conditions of the test described above it was difficult to determine quality on the basis of taste without losing essential weight data. Hence a number of additional fruits were wrapped in moistureproof Cellophane and beginning at 14 days, one or more fruits were unwrapped every day, weighed and tested for quality.

Results and Conclusions

In both years the moistureproof Cellophane decidedly retarded the loss of weight, and hence the cucumbers in this wrapper remained in storage on the average 26.4 to 35.4 days as compared with less than 8 days for the nearest Cellophane treatments. (See Table I.) In 1934 the waxed paper treatment came the nearest to the moistureproof Cellophane in retarding loss of weight, by keeping the fruits on the average 30.7 days. There was not much choice between the performance of the P. T., S. S. T., and S. A. T. grades of Cellophane, although the first was the poorest and the last the best. Under some conditions all of them allowed the cucumbers to deteriorate faster than those in the check. In 1934 the P. T. grade gave decidedly less favorable results than did the check. (See Fig. 2 and Table I.) A possible explanation of this is that in the case of fruits which are unwrapped the epidermis hardens quicker than under wrapped conditions, and loss of water through transpiration is hence reduced sooner than where the fruits are wrapped. A wrapper probably creates around each fruit a more or less humid condition which prevents the epidermis hardening rapidly. Under such conditions loss of water is controlled to a greater extent by the permeability of the wrapper. In the case of a very permeable one like the P. T. Cellophane, the rate of loss may be faster than where there is no wrapper at all.

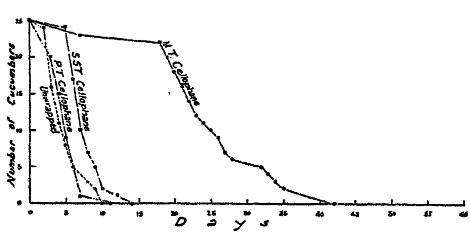

Fig. 1. Relation between number of days and number of cucumbers remaining above 85 per cent of their original weight when stored in different wrappers in 1933.

Other observations also contributed to this theory. There was a tendency for all fruits to lose weight more slowly as time elapsed and this was particularly noticeable in the larger more mature fruits. Presumably the epidermis of these fruits already partially hardened when placed in storage quickly reached a stage where it reduced

TABLE I—NUMBERS OF DAYS CUCUMBERS REMAINED UNDER VARIOUS STORAGE CONDITIONS BEFORE REACHING 85 AND 90 PER CENT OF THEIR ORIGINAL WEIGHT

Treatment	Days to Reach 85 Per cent in 1933			Days to Reach 85 Per cent in 1934			Days to Reach 20 Per cent in 1934		
	Least	Most	Aver-age	Least	Most	Aver-age	Least	Most	Aver-age
Unwrapped (Check)......	2	10	5.0	3	14	7.9	2	7	4.0
P. T. Cellophane.	3	11	5.1	3	10	5.0	2	6	3.2
S. S. T. Cello-phane........	5	14	7.8	5	13	7.5	3	8	4.9
S. A. T. Cello-phane........	—	—	—	6	11	7.8	3	8	5.2
M. T. Cello-phane*.......	18	42	26.4	26	50	35.4	18	38	26.3
Waxed Paper*...	—	—	—	14	50	30.7	9	36	18.4

*Averages and ranges in these treatments are based on less than 25 fruits as some fruits decayed and only healthy plants were considered.

water loss to a minimum. Where they were unwrapped this stage was evidently reached earlier, as can be seen in Fig. 2. It will be noticed that the unwrapped cucumbers were reaching 85 per cent of their original weight faster than the S. S. T. and S. A. T. grades of Cellophane up to the sixth day, after which they slowed down and for the remainder of the test lost weight much more slowly. The flattening out of all the curves towards their ends in Figs. 1, 2, and 3 illustrates the slowing up in loss of weight shown by the more mature fruits in all treatments.

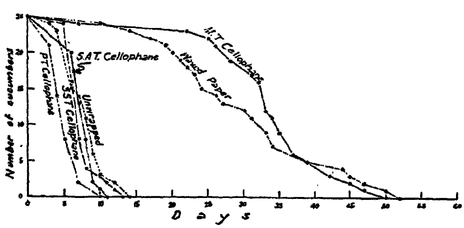

FIG. 2. Relation between number of days and number of cucumbers remaining above 85 per cent of their original weight when stored in different wrappers in 1934.

When the test was concluded at the time the fruits had lost 10 per cent (see Fig. 3) there was a much greater consistency of performance for all treatments than was shown when the test was carried to a 15 per cent loss. This was due to the fact that the increasing reduction in rate of loss of weight did not come noticeably into effect before the 10 per cent stage was reached. Incidentally fruits which

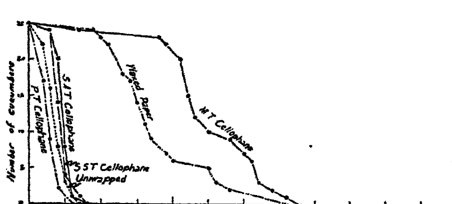

FIG. 3. Relation between number of days and number of cucumbers remaining above 90 per cent of their original weight when stored in different wrappers in 1934.

had lost only 10 per cent of their original weight were generally more fit for use than those allowed to lose 15 per cent, except those in the moistureproof Cellophane and waxed paper wrappers. Quality tests based on taste indicated that fruits stored longer than 20 days began to be unpalatable around that time, irrespective of their loss in weight.

Moistureproof Cellophane prevented a loss of weight as great as 10 per cent for as long as 18 to 38 days, with an average of 26.3 days in 1934. (See Table I.) Waxed paper held the fruits 9 to 36 days, with an average of 18.4 days. Assuming that on the basis of usability the limit of storage under the relatively high room temperatures of 80 degrees F is 20 days, then the moistureproof Cellophane was the most satisfactory material in the test.

The impermeability of moistureproof Cellophane to water created a problem however. Within 24 hours from the time the fruit was wrapped there was a noticeable condensation of water on the inner surface of the moistureproof Cellophane wrapper, and usually 20 days later it was still visible. In no other treatment was this condensation of water ever observed. In both this treatment and that of the waxed paper which undoubtedly also created a very humid condition around the fruit even if there was no visible water of condensation, decay eliminated some of the fruits before they had reached the required 10 or 15 per cent losses in weight. Decay never occurred in any other treatment. In 1933, 12 per cent of the cucumbers wrapped in moistureproof Cellophane decayed, and in 1934 there were as many as 36 per cent decayed. Those decaying before 20 days amounted to only 8 per cent in 1933 and but 4 per cent in 1934. Still fewer decayed under the waxed paper wrappers. In the majority of cases decay began at the stem end of the fruit, and could undoubtedly have been greatly reduced by harvesting the fruit with a part of the stem always attached rather than tearing the fruit free of it as is the common practice of the section.

These experiments indicate great possibilities for keeping cucumbers in good edible conditions at relatively high room temperatures by wrapping them in a material relatively impermeable to water. Moistureproof Cellophane besides proving the most desirable of the few materials used in these tests, had the advantage of enhancing the appearance of the cucumber. However dull the surface of the fruit became, it always looked bright and fresh through the Cellophane. The green color of the skin was usually well maintained. These factors would be of value to the vegetable dealer storing fruit on the open shelves in a store, a purpose for which Cellophane would seem admirably suited.

While no shipping tests have as yet been made, these storage tests indicate that there would be around 20 days for shipped cucumbers to reach northern markets and the ultimate consumer, when wrapped in moistureproof Cellophane. Whether such a method would be entirely feasible remains to be seen. Other factors such as temperature might become important. A small preliminary test indicates that the length of storage under the wrapping conditions described in this paper can be considerably increased by refrigeration.

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Some Factors Affecting Color in Carrots

By JULIAN C. MILLER, F. D. COCHRAN, and O. B. GARRISON, *Louisiana State University, Baton Rouge, La.*

IN 1932 a series of experiments was set up to determine the factors affecting color in carrots when grown under Louisiana conditions.

METHODS AND MATERIALS

The size of plots used in all of these experiments was 3.5x40 feet. To partially overcome soil variation, each treatment was replicated 5 times. Except in the fertilizer experiments, a 4–12–4 fertilizer derived from nitrate of soda, superphosphate, and muriate of potash was applied in the row at the rate of 800 pounds per acre. The plantings were made on raised beds, 10 to 14 inches high, with the exception of the tests made in the furrows between the beds. A selected strain of Danver's Half Long was used in all experiments. Plantings for winter studies were made October 1 to 10; for spring studies, January 15 to 20; and for fall trials, August 1 to 10.

The standard for color readings was based on a color chart prepared by the Bureau of Agricultural Economics, U. S. Department of Agriculture, for Federal shipping point inspection. The chart indicates the color requirement of a well colored, a fairly well colored, and a poorly colored carrot. The roots were washed and graded for color while wet. The number of roots in each color grade is expressed in per cent.

DISCUSSION OF RESULTS

The effect of fertilizer on color of carrots:—Since there was a variety of ideas as to the influence of certain fertilizer elements on the color of carrots, a large number of treatments was included in this test. Nitrogen was varied from a check which contained no nitrogen to 2, 4, and 6 per cent; phosphorus, from check to 4, 8, 12, 14, and 16 per cent; and potash, from check to 4, 8, 12, and 16 per cent. When one element was varied, the other two were held constant. The fertilizer was applied at the rate of 800 pounds per acre. A rate of application test which varied from a no-fertilizer check to 400, 800, 1200, and 1600 pounds per acre was also included.

Assuming that carotene formation may be governed by one of the less commonly applied fertilizer elements, a special fertilizer was applied, designated as an A to Z mixture made from boric acid 5 pounds, $MnSO_4$ 20 pounds, $CuSo_4$ 20 pounds, $BaCl_2$ 10 pounds, KI 5 pounds, and $ZnSO_4$ 5 pounds. To facilitate uniform distribution, these salts were applied in solution in the row before planting.

Preliminary fertilizer experiments were carried on during the winter of 1932–33, and the more complete experiments as just described were repeated during the winter, 1933–34, and again during the spring of 1934. In studying the effect on color of the varying percentages of each fertilizer treatment an average of 1200 carrots was examined. Since there were 23 combinations in the experiment, the total number of carrots examined was 27,600.

While many of the fertilizer treatments had a definite influence on the type of growth of both tops and roots, nevertheless there was no constant or significant influence on color.

Relation of varieties and strains to color:—One of the first phases of this problem was to determine if any of the commercial varieties or strains were resistant to off-color. Study of this problem was started in the fall of 1930 in connection with the variety standardization work in cooperation with the Bureau of Plant Industry. This work was carried on for 3 years, two plantings being made each year, in the fall and spring. Several strains of each of the following varieties were used: French-Forcing, Ox-heart, Scarlet Horn, Nantes, Chantenay, Danver's Half Long, Emperator, and Long Orange. These carrots were grown on the experiment station plots, on a soil known as Lintonia Silt Loam.

From color readings made throughout the period of the experiments, it was found that all varieties and strains were about equally subject to off-color. However, there were two varieties, Scarlet Horn and Nantes, that showed a slightly better color than other varieties. Also in more recent studies it was found that there were strains of Danver's Half Long that showed increases of well colored carrots as much as 6 per cent above other commercial strains. It was found that the fall and winter carrots averaged 25 to 30 per cent off-color, while the spring grown carrots averaged 10 to 15 per cent off-color. The percentage off-color varied from year to year or season to season although the same strains were used and the plantings were made on the same soil. The number of carrots examined in determining the above percentages was 24,000 from each of the fall and spring plantings.

The effect of different soil types and soil reaction on color of carrots:—It was evident from a previous survey that carrots developed better color in certain sections of the state than they did in others. To obtain data on the cause of this variation, experiments were set up in the fall of 1932. Plantings were made on Ridge Silt Clay at Cut Off, on Sharkey fine sand at Lockport, on Sharkey clay at Labadieville, Louisiana, and on Lintonia Silt loam at Louisiana State University. The first two places mentioned are located in the center of the principal carrot growing section of the state. Soil reaction was determined for each of the above soil types.

In order to study three distinct soil types under identical weather conditions, plantings were made at Louisiana State University in 1933. Two soils were made, one by mixing about 30 per cent of composted organic matter with silt loam, the other by mixing about 30 per cent river sand with silt loam. The third soil or check was the Lintonia silt loam, a bluff soil on the Station plots. The plots were staked out, a trench opened 10 inches wide and 6 inches deep and filled with the respective soil types mentioned above. All plots received the same cultural treatments throughout the growing period.

As shown in Table I, the Lintonia silt loam at Louisiana State University gave a significantly lower percentage of well colored roots than was produced on the other soil types. The other soil types are

better aerated than the Lintonia silt loam because of their greater content of sand and organic matter. This may account for the better color of carrots produced on these soils. It is also apparent in Table I that soil reaction had no significant effect on color.

TABLE I—INFLUENCE OF SOIL TYPE AND SOIL REACTION ON COLOR OF CARROTS

Soil Type and Location	pH	Color Classification—Per cent			Number of Plants
		Well Colored	Fairly Well Colored	Poorly Colored	
Part I: 1932					
Ridge silty clay, Cut Off, Louisiana.....	5.0	80.0	14.4	6.0	250
Lintonia silt loam, Louisiana State University..........................	5.5	43.6	28.2	28.2	362
Sharkey clay, Labadieville, Louisiana...	6.2	90.0	7.5	2.5	162
Sharkey fine sandy loam, Lockport, La.	7.1	84.5	12.6	2.9	206
Part II: 1933					
High organic matter soil............... Organic matter mixed with a silt loam Louisiana State University		7.6	37.5	54.8	1911
Sandy loam soil...................... Sand mixed with a silt loam, Louisiana State University		5.3	35.7	58.9	920
Lintonia silt loam.................... Used as a check, Louisiana State University		3.0	25.5	71.3	520

In Table I, Part II, it is again evident that carrots grown on the high organic matter soil and on the sandy soil had a significantly higher percentage of well colored and fairly well colored carrots than did those grown on the Lintonia silt loam.

Effect of height of seed-bed on color in carrots:—In order to obtain additional data showing the importance of drainage and aeration, plantings of carrots were made on beds 10 inches high and in the drainage furrows between these beds or ridged rows. Winter and summer plantings were made in this manner. Very striking results have been obtained as shown in Table II.

TABLE II—EFFECT OF HEIGHT OF SEED-BED ON COLOR IN CARROTS

Color Classification	10 Inches High		Planted in Furrow	
	Summer Planted	Winter Planted	Summer Planted	Winter Planted
	Per cent	Per cent	Per cent	Per cent
No. carrots classified	4091	400	2517	450
Well colored........	12.83	7.40	11.24	0.00
Fairly well colored..	60.10	19.60	46.72	1.10
Poorly colored......	23.71	72.80	41.27	98.80

It may be noted for both winter and summer plantings that better colored carrots were produced on the high seed bed while the poorer colored roots were grown in the furrow. The carrots that were

grown in the furrows during the winter practically failed to develop color at all. There was not a single carrot in the furrow planting that colored well enough to be grouped with the well colored roots. Commercially, carrots are never grown in furrow beds in Louisiana.

The water-holding capacity of the soil on which these carrots were grown is 24.9 per cent. The average soil moisture on the raised beds from November 15, to December 15, 1934, was found to be 21.7 per cent, while that in the furrow for the same period was 23.2, an average difference of 1.50 per cent. Whether this difference is responsible for the wide color variation found between the raised bed and furrow is yet to be determined. It is certain that the roots grown on the raised beds had a better chance for aeration than those grown in the furrow beds. During periods of rainy weather, feeding roots of carrots grown on raised beds often grow near enough to the surface to be easily seen. The tops of those grown in the furrow often turn yellow, showing signs of an excess of water or lack of air. Under such conditions the carrots often decay.

The effect of selection and breeding for color:—It has often been observed that regardless of how poor the color of the majority of the roots, there are usually a few that are well colored. A number of these well colored roots which were grown under adverse conditions have been selected for breeding. Some of these selections have been selfed while others were allowed to open pollinate. The results of two such selections compared with the parent strain grown under similar conditions may be seen in Table III.

TABLE III—THE INFLUENCE OF SELECTION AND BREEDING FOR IMPROVEMENT IN COLOR OF CARROTS

Seed Stock	Color Classification (Per cent)			Number of Roots
	Well Colored	Fairly Well Colored	Poorly Colored	
Danver's Half Long (Parent)....	3.00	25.50	71.3	524
Danver's Half Long ,F_1 (Open Pollinated)................	23.00	50.70	26.1	65
Danver's Half Long, F_1 (Selfed)..	24.70	49.50	25.70	97

The results show that the color of the F_1 selection was improved markedly over the parent strain, differing very little whether open or self-pollinated. The selfed selection naturally showed a wider range of segregation of plant characters than did the open pollinated plants. There was a marked reduction in vigor of the selfed plants, particularly noticeable when these selfed roots were planted for seed production.

Although all of the selections did not show the degrees of improvement shown in the above two selections, these results suggest that this method of breeding offers an opportunity of developing a strain of carrots that will color well even when grown under adverse conditions.

Alcohol-Insoluble Residue as an Index of Quality of Sweet Corn[1]

By R. R. JENKINS, *Experiment Station, Geneva, N. Y.*

THE quality of canned corn determines primarily its market value. Among the factors that are taken into account in arriving at an estimate of the quality grades of whole grain style of canned corn are color, absence of defects, cut, maturity, and flavor. The relative importance of each component has been expressed numerically on a scale of 100. Of these, the Bureau of Agricultural Economics of the U. S. Department of Agriculture (10) has scored flavor 25 per cent, and maturity 35 per cent of the total. Inasmuch as maturity is given major importance on this scale, any attempt to place the grading of corn for quality upon a quantitative basis will have for its most important problem that of the measurement of maturity, and consequently emphasis has been placed to this end.

The variety, climatic conditions, harvesting methods, cannery practices, and the natural properties of the corn itself have been reported as of great importance in determining the quality of the canned product (1, 3, 4, 6, 8, 9).

Culpepper and Magoon (3) found that the quality in sweet corn is determined primarily by the degree of maturity of the corn when canned.

Too heavy consistency due to the use of over mature corn is often avoided by the use of a greater proportion of liquor; but general toughness cannot be masked, and it is this factor more than anything else which unfavorably affects the quality of canned corn. This point has been emphasized by Burton (2) who found that commercial grades of canned Country Gentleman corn, as far as they are concerned by maturity, differ only in the proportion of tough and tender kernels present.

Attempts have been made to develop a method by which the maturity of corn in a can could be measured. Remington (7) found slight differences in the percentages of crude fiber in the analyses of canned corn, Crosby, Country Gentleman, Evergreen, and Golden Bantam varieties, and that these percentages increased with maturity. From the data presented, it is impossible to judge the amount of this tendency as the analyses were made of material secured from different sources and apparently without information as to the exact age of the corn when it was canned. Several years later, Burton (2) sought a practical means of determining maturity. He reported that the hulls of Country Gentleman corn did not thicken with increasing maturity, but that it did lose progressively in moisture content. The crude fiber analyses for the dry hulls alone showed a very uniform amount at different maturities. In furthering the answer to the problem of measurement of maturity, crude fiber analyses showed nothing of value in this respect. He also found that the specific gravity of the cut

[1]Journal Paper No. 89, of the New York State Agricultural Experiment Station.

kernels of corn had a direct bearing on the differentiation of old from young corn or tender from tough corn.

In the present study, the strains of corn used were as follows: Open-pollinated Golden Sunshine, Top-cross Golden Sunshine, Open-pollinated 10–14-rowed Golden Bantam, Top-cross 10–14-rowed Golden Bantam, Open-pollinated 8-rowed Golden Bantam, Top-cross 8-rowed Golden Bantam, Golden Cross Bantam, and a three-way cross (1339 x 1351 x 1313). The sampling of the different strains of corn was begun during the summer of 1933 upon ears at 18–20 days from the date when their silks first appeared and subsequent samples were taken at intervals of 2 days over a period of 10 days. The corn was processed under commercial specifications using brine mix of 15 pounds of salt and 35 pounds of sugar to every 132 gallons of water.

Chemical studies on the raw and canned product revealed that as the seed matures there is a loss of moisture and a definite storing up of starches and related solids. It has been found that when hot 80 per cent alcohol is used as a solvent, all sugars and some other compounds are dissolved, but that starches, hemicelluloses, fiber, and proteins remain insoluble. The proportion of these latter compounds increases in maturing corn; therefore, this proportion can serve as an index of maturity of the raw corn and might serve as an index of quality of the canned corn.

To determine the alcohol-insoluble residue in canned corn, the following procedure was adopted: The contents of the can were drained through a 10-mesh sieve, washed with about an equal weight of water and allowed to drain for 10 minutes. The corn was then run through a food chopper equipped with a fine grinder. Duplicate 50-gram samples were taken and sufficient 95 per cent alcohol added to bring the final concentration to 80 per cent, allowing for the moisture content of the sample. The contents were warmed on a steam bath for 30 minutes, cooled and the alcohol solution poured through an extraction thimble, catching the filtrate in an extraction flask. The residue was transferred to the thimble, allowed to drain, and then emptied into a tared weighing bottle and dried at 80 degrees C over night. The residue was then weighed and ground so that all the particles would pass through a 1-mm sieve. The loss of sample due to grinding was recorded. Finally, the residue was transferred to the extraction thimble and extracted with 80 per cent alcohol in the Soxhlet apparatus until the extract was free from soluble carbohydrates (Molisch test). The residue was dried in a tared weighing bottle to a constant weight at 80 degrees C. The alcohol-insoluble residue was then calculated on a fresh weight basis and the results presented in Table I.

Since this work was begun, Kertesz (5) has reported a method for the rapid determination of alcohol-insoluble residue in canned peas. Comparisons of the two methods (see Table I) show a lower percentage of residue content according to his method and approximately the same range of magnitude between the different pickings. Inasmuch as Kertesz's method for determining alcohol-insoluble residue is a more rapid one, lower percentage ratings were obtained and the

quality index values given here would not be applicable to the results obtained from his method.

An official quality grading test was made on a set of canned samples from each of the various strains of corn by a representative from the U. S. D. A., Bureau of Agricultural Economics, Washington, D.

TABLE I—RESULTS OF QUALITY RATING TESTS BASED ON MATURITY

Date Sampled	Canned Corn				Raw Corn		
	No. Days from Silking	Total Solids (Per Cent)	A. I. R.* (Per Cent)	Official Quality Rating	Total Solids (Per Cent)	A. I. R.* (Per Cent)	Kertesz's Method
			Open-pollinated Golden Sunshine				
8/12/33	20	—	—	—	22.56	16.76	—
8/14/33	22	23.51	19.07	34	27.25	21.27	—
8/16/33	24	24.90	20.66	34	27.61	22.57	—
8/18/33	26	26.78	22.23	27	32.88	25.80	—
8/21/33	29	28.16	23.25	23	35.82	27.92	—
			Open-pollinated 8-rowed Golden Bantam				
8/15/33	20	21.76	17.57	—	26.21	19.89	—
8/17/33	22	23.86	18.87	34	30.46	23.25	—
8/19/33	24	25.96	21.15	30	32.97	26.11	—
8/21/33	26	26.78	21.55	28	33.96	26.59	—
8/23/33	28	28.57	23.00	24	34.56	27.88	—
			Top-cross 8-rowed Golden Bantam				
8/19/33	19	21.73	17.02	31	28.60	21.56	—
8/21/33	21	22.88	17.94	34	28.29	21.19	—
8/23/33	23	23.42	18.77	33	26.22	21.01	—
8/25/33	25	24.06	19.09	31	27.65	21.89	—
8/28/33	28	25.79	20.60	27	32.33	25.68	—
			Golden Cross Bantam				
8/22/33	18	18.69	13.78	31	22.74	16.28	—
8/24/33	20	20.67	16.53	34	25.17	20.28	—
8/26/33	22	22.31	17.53	33	25.15	20.13	—
8/28/33	24	25.59	20.10	32	29.74	23.93	—
8/30/33	26	26.61	21.32	30	31.30	25.34	—
			Top-cross Golden Sunshine				
8/25/33	25	—	19.91	30	—	—	18.51
			Open pollinated 10–14-rowed Golden Bantam				
8/21/33	21	—	19.77	31	—	—	18.37
8/23/33	23	—	20.55	28	—	—	18.39
8/25/33	25	—	20.67	26	—	—	18.44
8/28/33	28	—	23.02	22	—	—	21.73
			Top-cross 10–14-rowed Golden Bantam				
8/25/33	25	—	18.33	28	—	—	17.10
8/28/33	28	—	21.23	26	—	—	20.72
8/30/33	30	—	21.46	23	—	—	20.73
			3-Way cross (1339 x 1351 x 1313)				
8/28/33	26	—	19.22	31	—	—	18.25
8/30/33	28	—	21.32	29	—	—	—

*Alcohol insoluble residue.
Duplicate samples checked within 0.25 of a per cent.

C. The results, based on maturity alone, are shown in Table I. Service and Regulatory Announcements (10) give the following specifications for a maturity rating: "A", Fancy grade, 31–35 points; "B", extra standard grade, 26–30 points; "C", standard grade, 21–25 points; and "D", sub-standard grade, 0–20 points.

All the strains of corn yielded a tender and sweet product at the first picking date, 18–20 days after silking, but were lacking in body and flavor and were classed as slightly too immature for fancy grade. On the basis of maturity alone, however, a rating of 31 points was given or fancy grade. The figures in Table I show a relatively low percentage of alcohol-insoluble residue, indicating a slightly immature corn. At 28 and 29 days maturity, the open-pollinated strains were classed as standard grade. Correlated with this stage of maturity, the results show a decided increase in the percentage of alcohol-insoluble residue.

During the entire period studied, the percentages of total solids and alcohol-insoluble residue increased in the same ratio in each strain of corn, in the raw and canned alike. This ratio differed slightly, however, between the various strains of corn.

In Table I, the results show that an alcohol-insoluble residue content of less than 20.5 per cent indicates fancy grade; a greater percentage of alcohol-insoluble residue content up to 23.0 per cent indicates extra standard grade.

A discrepancy is noted in the third picking of the top-cross 10–14-rowed Golden Bantam corn. The alcohol-insoluble residue content was 18.33 per cent and received a maturity rating of 28 or extra standard grade. This strain of corn matures very irregularly and it is possible that this fact may account for the irregularity in the grading as shown.

In the top-cross Golden Sunshine, the alcohol-insoluble residue was 19.91 per cent and received a rating of 30 or extra standard grade. Inasmuch as the other strains of corn studied showed a grading of 31 or fancy grade for a similar residue content, it is possible that the personal opinion of the man doing the grading may have been variable.

Several commercial packs were analyzed for residue content and the results recorded in Table II.

The "A" brand (see Table II) of whole kernel corn, altho labeled fancy quality, was classed as standard grade by expert graders. When the quality index is applied, this lower rating appears to be true, since it showed a high percentage of alcohol-insoluble residue.

The per cent of alcohol-insoluble residue expressed on a fresh weight basis can not be used as an index of quality of cream style canned corn because the commercial practice in canning this style of corn is to add more water and live steam to more mature corn in the cooking or creaming process. This additional water is taken up by the increased amount of starch in more mature corn. Therefore the total solids and the alcohol-insoluble residue in the drained weight of the canned corn would vary greatly in the cream style pack and an index based on a fresh weight basis would not be reliable. This is illustrated in Table II in which the extra standard grade of cream

TABLE II—ANALYSES OF RESIDUE CONTENT

Commercial Brands of Canned Corn Used	A. I. R.* (Per Cent) (Fresh Weight Basis)	A. I. R.* (Per Cent) (Dry Weight Basis)	Quality Rating
A................	25.39	——	Standard, whole kernel
B................	19.07	77.07	Fancy, whole kernel
C................	19.01	78.46	Fancy, whole kernel
D................	17.55	69.84	Fancy, cream style
E................	15.96	74.52	Extra Standard, cream style
F................	16.55	——	Fancy, cream style
G................	20.08	——	Fancy, cream style
H................	18.93	65.34	Extra Standard, cream style
I................	17.57	——	Fancy, cream style
J................	18.13	——	Fancy, cream style
K................	16.35	66.89	Extra Standard, cream style
L................	13.06	70.32	Sweetened field corn
M................	——	72.32	Extra Standard, cream style

*Alcohol-insoluble residue.

style corn had a lower alcohol-insoluble residue than the fancy grade in many cases although the extra standard corn was more mature. When the percentages of alcohol-insoluble residue are calculated on a dry weight basis, however, the extra standard cream style showed a higher residue content than the fancy cream style corn.

In the consideration of these figures and the preceding discussion of them, it must be borne in mind that only a few strains and varieties of whole kernel and cream style of canned corn have been included in the present experiments. The results show, however, that the alcohol-insoluble residue content is not applicable as an index of quality in the cream style corn but does offer definite possibilities as a quality index in the whole kernel style of canned corn. Further residue studies in this relation should be made over a period of years on a large number of varieties from different localities and from different commercial packers.

In conclusion with the whole kernel style of canned corn of the varieties studied, the results show that with a percentage alcohol-insoluble residue of 20.5 per cent or lower, the corn may be classified as fancy grade, and with an alcohol-insoluble residue content between 20.5 per cent and 23.0 per cent, the corn falls into the extra standard grade. An alcohol-insoluble residue content above 23.0 per cent would indicate standard grade or lower.

No quality index values were obtained on either a fresh or dry weight basis which would be applicable to both the whole kernel and cream style of canned corn. Alcohol-insoluble residue content cannot be used as an index of quality in the cream style of canned corn.

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Pungency of Onions in Relation to Variety and Ecological Factors[1]

By HANS PLATENIUS and J. E. KNOTT, *Cornell University, Ithaca, N. Y.*

THE question has frequently been raised as to whether or not a measurable difference exists in the pungency of onions from different varieties and as to how the strength of onions may be affected by environmental conditions. Heretofore no such study has been undertaken because the only measure of pungency available was the tasting test which on the whole is very inaccurate because of the accumulative effect of successive tastings.

A more satisfactory measure of pungency in onions became available through the development of a chemical method which made it possible to express the results in definite numerical values. This method is based on the quantitative determination of sulfur in the volatile onion oil after the latter has been isolated by means of steam distillation. Details of the procedure will be published elsewhere.

Onion samples of different varieties grown in various parts of the United States during 1934 were obtained from several collaborators[2]. These samples of onions were raised in connection with a study of onion types commonly grown in this country. With the exception of the samples from Ithaca, New York, all onions were grown from seed furnished by the United States Department of Agriculture.

The results of this study are given in Table I. With respect to variations in pungency of different varieties small inconsistencies are obvious. For instance, it would be difficult to decide from the data given whether Early Grano is milder than Sweet Spanish or vice versa. Variable growing conditions apparently have different effects on the same variety. Nevertheless, the varieties included in this study can easily be grouped into several classes. Under A appear those varieties which are distinctly mild; under B those which are intermediate in pungency; and under C are listed varieties which are decidedly strong. With an increasing demand for mild onions California Early Red and Early Grano may be expected to become leading commercial varieties. It is surprising to note that according to these data neither Yellow Bermuda nor Crystal Wax can be classified as distinctly mild. From the values obtained for the pungent group it would appear that Ebenezer is even stronger than Australian Brown while Red Creole seems to be the most pungent type of the varieties listed. These very strong types should serve as valuable material for the commercial preparation of onion powder or salt for flavoring purposes.

The effect of environmental conditions appears to be less pronounced than that of variety. Although the onions were grown in widely separated localities differences in pungency as a result of

[1]Contribution 125 from Department of Vegetable Crops, Cornell University.

[2]The writers are indebted to Dr. H. A. Jones, Dr. H. D. Brown, Prof. L. R. Hawthorn, Dr. A. L. Wilson, Prof. Grant B. Snyder, and particularly Dr. Roy Magruder for supplying the onion samples.

TABLE I—VOLATILE SULFUR CONTENT OF DIFFERENT VARIETIES OF ONIONS GROWN AT VARIOUS EXPERIMENT STATIONS

Volatile Sulfur in Parts per Million of Fresh Weight

Source of Onions	A				B						C			
	Calif. Early Red	Early Grano	Sweet Spanish	Utah Sweet Spanish	Yellow Ber-muda	Crystal Wax	Yellow Globe Danvers	South-port White Globe	South-port Yellow Globe	South-port Red Globe	White Portu-gal	Aus-tralian Brown	Eben-ezer	Red Creole
Winterhaven, Tex..	—	59.8	59.0	—	—	80.9	—	—	—	—	—	—	—	121.9
Arlington, Va......	—	70.4	87.8	—	90.2	—	85.2	—	—	—	—	—	105.4	128.0
Logan, Utah.......	95.4	—	—	91.4	—	—	128.6	139.4	125.6	125.4	141.3	—	120.9	—
Amherst, Mass.....	—	74.3	85.1	—	102.2	—	104.5	—	—	—	—	—	158.4	—
Ithaca, N. Y.......	—	—	—	91.1	—	—	112.4	—	—	—	—	—	—	—
McGuffey, O.......	—	97.1	80.1	—	—	—	120.6	—	—	123.0	148.2	148.8	167.7	—
Davis, Calif........	60.5	—	—	107.4	113.8	129.8	134.4	145.3	—	—	—	147.2	198.3	—

ecological conditions were relatively small, though fairly consistent. Surprising is the fact that samples from California were in general more pungent than those from any other state included in this study, thus refuting the common belief that onions produced in the West are always milder than those from Eastern states. Studying certain climatic variables given in Table II no definite correlation could be established between pungency and climatic conditions. However, such a correlation could hardly be expected since the accumulation of onion oil in the bulbs is undoubtedly controlled by several factors and the effect of each may be obscured by other variables. It also must be realized that some varieties were harvested a month or more earlier than others grown at the same station. Still, the results suggest that temperature, particularly during the ripening period and possibly the relative humidity play an important role in determining the relative strength of the bulbs. Experiments under controlled conditions are under way and they are expected to give more reliable information on the environmental factors which cause onions to become strong or mild.

TABLE II—DATA ON ENVIRONMENTAL CONDITIONS AT THE DIFFERENT EXPERIMENT STATIONS DURING THE GROWING SEASON

	Soil Type	Average Hours of Sunshine Per Month	Average Relative Humidity (Per cent)	Mean Temperature (Degrees F)	Mean Temperature During Last Month of Growing Season (Degrees F)
Winterhaven, Tex.	Sandy loam	199	49	63.3	72.6
Arlington, Va.	Silt loam	281	50	69.6	80.8
Logan, Utah	Gravelly Sandy loam	343	23	73.5	77.8
Amherst, Mass.	Sandy loam	270	65	66.1	65.0
Ithaca, N. Y.	Sandy loam	277	47	67.2	66.0
McGuffey, O.	Muck	322	55	74.4	73.2
Davis, Calif.	Silt loam	375	44	67.9	75.2

In a preliminary study carried out in the greenhouse in the spring of 1934 the effect of three soil types was studied. About 30 onions were grown in several large drums provided with a constant water table. The results shown in Table III suggest that onions grown in a sandy soil with plenty of moisture can be expected to be milder than those raised on muck or loam. This agrees well with the report that the Red Italian onions imported from Italy and known for their extreme mildness (Table III) are produced on a black sandy soil.

TABLE III—EFFECT OF SOIL TYPES ON THE VOLATILE SULFUR CONTENT OF RED ITALIAN ONIONS

Sample	Muck	Loam	Sand
	p.p.m.	p.p.m.	p.p.m.
Grown in greenhouse	64.3	68.0	39.9
Imported from Italy	—	—	28.5

Total Soluble Solids and Sugars in Watermelons

By D. R. Porter and C. S. Bisson, *University of California, Davis, Calif.*

IN California, the Klondike watermelon is the only variety of commercial significance. When grown here in comparison with such varieties as Tom Watson, Thurmond Gray, and Pride of Muscatine, the Klondike tastes much sweeter than any of the others. Whether this sweetness is a constant varietal characteristic or whether it is a direct response to regional environment is unknown.

In the course of watermelon-breeding investigations, adequate measurement of variation and constancy of sugar content entails examination of very large numbers of individual fruits. As new Klondike strains were developed and released (1), growers and seedsmen seemed as much concerned with relative sweetness as with yield, type, and other horticultural qualities. In breeding for resistance to Fusarium wilt, the resistant varieties, Pride of Muscatine and Iowa Belle (2), have been crossed with certain Klondike strains. The two former varieties, particularly Pride of Muscatine, are relatively low in both total soluble solids and total sugars. In evaluating these resulting hybrid strains, a rapid and accurate method for determining relative sweetness had to be found.

By means of the Brix hydrometer, it was possible to obtain density readings that indicated indirectly the per cent total soluble solids in the extracted juice; but this method, although reasonably accurate, proved too slow for the large number of fruits to be sampled. Determination of per cent total soluble solids[1] by a large Spencer refractometer indicated the same relative trend in total solids as that in total sugars as determined by chemical analysis. This method was also too slow, as samples of juice had to be collected in vials in the field and brought to the laboratory for the determinations. Finally a small Zeiss hand refractometer was used. Although somewhat less accurate than either the Spencer refractometer or the Brix test, it had the advantage of adaptability to field conditions and proved about three times as rapid as the Spencer. It is accurate to 0.2 per cent; and, as preliminary trials showed, it yielded the same relative determinations as either the Spencer or Brix.

The refractometer detected extreme variations in total soluble solids of individual fruits and of composite samples from several varieties and strains. It did not, however, prove that there were significant differences in total sugar content, although fruits with a relatively high refractive index tasted much sweeter (to several individuals) than those whose refractive index was relatively low.

Chemical analyses were compared with refractometer and Brix readings, using juice from individual fruits as well as composite samples representing from 3 to 20 fruits. Total sugars and reducing sugars were determined by the Quisumbing-Thomas method. Thus

[1]The refractometric readings give the actual density; and from the factor thus secured the total per cent soluble solids is obtained by interpolation, using Table V from Brown's Handbook of Sugar Analysis.

it was possible to ascertain whether a constant ratio existed between total soluble solids and total sugars in the expressed juice and to determine the ratio of monosaccharides to disaccharides.

The results of one of the preliminary trials appear in Table I. The per cent total soluble solids was determined with the Spencer refractometer for California Klondike Nos. 4, 8, and 1. The fruits had been tagged and dated at anthesis, and they were of the same approximate age when picked. There was a slight, probably insignificant variation in total soluble solids of the three strains. Likewise, there was no significant difference in per cent of total sugars in them. For these strains, however, the ratios of the per cent total sugars to the per cent total soluble solids are nearly alike, varying from 0.793 to 0.823. Variation in the total per cent solids seems to depend largely upon variation in the total per cent sugar content.

TABLE I—RELATIVE REFRACTIVE INDEX AND TOTAL SUGARS IN THREE CALIFORNIA KLONDIKE STRAINS, 1933*

Strain	Total Soluble Solids† (Per cent)	Sugar Content, (Per cent)			Ratios	
		Reducing Sugars as Invert	Sucrose	Total as Invert	Total Sugars to Total Soluble Solids	Disaccharides to Monosaccharides
California Klondike No. 4	12.2	3.52	6.40	9.92	0.813	1.818
California Klondike No. 8	11.9	3.58	5.78	9.36	0.793	1.609
California Klondike No. 1	12.4	3.72	6.48	10.20	0.823	1.742

*Each sample consisted of 50 cc. of juice from each of 20 melons of each strain, the fruits being 55 to 60 days old, or about 10 to 15 days overripe.
†As determined with the Spencer refractometer.

The data in Table I were secured from overripe fruits, as Klondike fruits at Davis normally mature in approximately 45 days after anthesis. Table II presents data on similar trials with immature, mature, and overripe fruits. The total soluble solids increased from 10.08 to 11.85 per cent as fruit age increased from 30 to 65 days. In like manner, the per cent total sugar increased from 8.02 to 9.53. Again the ratios of the per cent total sugars to the per cent total soluble solids were close, ranging from 0.795 to 0.808. As Table I shows, the disaccharide-monosaccharide ratio was nearly constant among the three strains. All fruits were of the same approximate age. In Table II, this ratio increased from 0.189 for immature to 0.818 for mature and to 1.731 for overripe fruits, although the ratios of the per cent total sugars to the per cent total solids in the mature and overripe fruits were practically identical.

The results just described were secured with strains of California Klondike. Similar tests were conducted with additional varieties, and the data in Table III show that mature Klondike fruits contain a higher per cent total solids and total sugars than the other four varieties and that the ratios of the per cent total sugars to the per cent total soluble solids vary more than those of the Klondike strains. Al-

TABLE II—DEGREE OF MATURITY AS RELATED TO THE RATIOS OF TOTAL SUGARS TO TOTAL SOLUBLE SOLIDS AND OF DISACCHARIDES TO MONOSACCHARIDES IN CALIFORNIA KLONDIKE NO. 3 AT DAVIS, 1933. COMPOSITE SAMPLES USED

Degree of Maturity	Total Soluble Solids* (Per cent)	Sugar Content (Per cent)			Ratios	
		Reducing Sugars as Invert	Sucrose	Total as Invert	Total Sugars to Total Soluble Solids	Disaccharides to Monosaccharides
Immature, average approximately 30 days............	10.08	6.74	1.28	8.02	0.795	0.189
Mature, average 50 days............	11.53	5.12	4.19	9.31	0.808	0.818
Overripe, average 65 days............	11.85	3.49	6.04	9.53	0.804	1.731

*As determined with the Spencer refractometer.

though the causes of this variation are not yet definitely known, fluctuations in dissolved solids other than sugars may be responsible.

TABLE III—TOTAL SOLUBLE SOLIDS AND TOTAL SUGARS IN COMPOSITE SAMPLES OF MATURE WATERMELON FRUITS OF VARIOUS VARIETIES AT DAVIS, 1933

Variety	Total Soluble Solids (Per cent)	Total Sugars (Per cent)	Ratio of Total Sugars to Total Soluble Solids
Pride of Muscatine..................	8.85	7.21	0.732
Iowa King........................	9.05	7.49	0.828
Thurmond Gray....................	10.55	8.17	0.774
Iowa Belle........................	10.85	8.94	0.824
California Klondike No. 3...........	11.80	10.39	0.880

With individual fruits this ratio of total sugar to total soluble solids is somewhat less consistent than for composite samples; but, if there is a significant difference in total soluble solids, it is usually, although not always, accompanied by a similar significant difference in total sugars. This is shown in Table IV. The ratios varied from 0.685 for fruit No. 1 to 0.891 for fruit No. 17, a variation too great to result entirely from error of sampling or reading. It has been noted that among three or four mature fruits on a single plant there may be a difference of slightly more than 1 per cent in per cent total soluble solids, total sugars, or both. The sugar-solid ratios in these instances do not always parallel. When the juice of these three or four fruits is mixed, however, a comparative ratio is secured. It seems probable that individual fruits may contain relatively more non-sugar soluble solids than others. This possibility is being investigated.

The investigations were continued and expanded in 1934; and though space does not permit a detailed discussion, it may be stated that the results closely parallel those secured in 1933 and indicate

TABLE IV—CORRELATION OF TOTAL SOLUBLE SOLIDS AND TOTAL SUGARS IN INDIVIDUAL FRUITS OF COMMERCIAL KLONDIKE WATERMELONS AT DAVIS, 1933

Fruit No.	Total Soluble Solids (Per cent)	Total Sugars (Per cent)	Ratio of Total Sugars to Total Soluble Solids
1	11.85	8.12	0.685
2	12.85	9.83	0.765
3	11.15	8.27	0.741
6	12.40	8.86	0.715
7	11.50	9.78	0.850
11	11.30	8.72	0.771
12	11.85	9.43	0.796
13	11.60	9.20	0.798
14	11.30	8.69	0.769
15	12.00	9.23	0.769
16	12.10	9.70	0.801
17	10.30	9.18	0.891
18	11.90	9.23	0.691
19	11.85	9.97	0.841
20	10.85	9.06	0.835
21	11.50	9.87	0.858
22	11.45	9.77	0.853
23	11.25	9.61	0.854
24	11.35	9.16	0.807

again that the refractometer indirectly detects significant variation in the sugar content of composite samples of extracted juice. The 1934 results further indicate that in immature fruits of the Klondike variety, the per cent of monosaccharides is considerably higher than the per cent of disaccharides. As the fruit approaches maturity this ratio gradually reverses itself, until in overripe fruits the disaccharide is much higher than the monosaccharide content. The total sugar content does not increase appreciably, however, after the fruit reaches an age of 45 days; the ratio of the two sugar groups merely becomes reversed.

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The Influence of Soil Acidity and Soil Type Upon the Growth and Composition of the Lima Bean Plant

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IT is significant that the growth and composition of plants vary from region to region and upon the various soil types within a given section. Many painstaking attempts have been undertaken to establish definite relations between plant growth and the ionic composition in the plant ash. These have in general been unsatisfactory. It is, however, an established fact that the ionic concentration and composition of the soil solution greatly influence the growth and composition of the plant. The following discussion treats of the effect of the soil reaction and calcium ion as a variable upon the growth and composition of the Henderson bush lima bean plant.

EXPERIMENTAL PROCEDURE

The soils used for the study were: Portsmouth loamy fine sand, a dark colored and poorly drained soil, high in organic matter and with a low pH value; Bladen sandy loam, a light colored and poorly drained soil, medium in organic matter and with a low pH value; and Norfolk fine sand, a light colored and well drained, relatively highly weathered soil with low organic matter content and fairly high pH value. The pots, 2-gallon coffee urn lining type with a hole in the bottom, were filled with soil to within 1 inch of the top. This required 6300, 6800, and 7700 grams of soil for the Portsmouth, Bladen, and Norfolk, respectively. The soil had been limed about a year previously with hydrated lime and four different crops had been subsequently grown in the soil. The soil was limed again before planting the lima beans.

Ten seeds of Henderson bush lima were planted in each pot on May 14, 1934, and later thinned to five plants. The crop was fertilized with 1 gram of ammophos, 1 gram urea, and 1 gram of muriate of potash per pot on May 29, and with one-half the above quantity on June 29. The plants were harvested on July 6, oven dried and ground for analysis. The bean pods were well set, but not mature when harvested. These were weighed separately, but included in the sample for analysis. The pH value and yields together with the results of the analyses are given in Table I. Table II shows the total milliequivalents of nutrients removed per pot. Each figure represents an average of data from five pots in the Portsmouth and two in the Bladen and Norfolk soils.

SOIL DATA

The results of the soil analyses for replaceable calcium oxide indicate the different natures of the soils. The Portsmouth soil was more strongly buffered than the Bladen and the Bladen more than the Norfolk. However, the leaching of the calcium ion was controlled by the soil colloidal complex and anions unabsorbed by the plant.

The plant, for example, showed selective absorption to a certain extent for the anions. Then, there was left in the soil unabsorbed chlorine ions from the potassium chloride added. When the soil was leached these ions were removed and with them was carried chiefly calcium at high pH values and potassium at low pH values. The quantity of calcium leached increased as the soil reaction rose, but not in proportion to the quantity of replaceable calcium present. The quantity of potassium leached, on the other hand, decreased at high pH values due to plant absorption. Aluminum appeared in solution at pH 3.9 to pH 4.4 in the Portsmouth, 4.2 in the Bladen, and 5.2 and below in the Norfolk soil. This, of course, was directly responsible for the low yields at these pH values. The complete data on this phase of the problem are given in a paper to be published in Soil Science.

TABLE I—THE INFLUENCE OF SOIL ACIDITY UPON THE GROWTH AND COMPOSITION OF THE LIMA BEAN PLANT

Mean pH Soil[1]	Green Weight Pods[2]	Total Dry Weight[2]	Calcium[3]		Percentage of Each Nutrient[4]				
			Replaceable	Leached	Ca	Mg	K	N	P
			Portsmouth Loamy Fine Sand						
3.9	11	11	950	134	10	6	18	60	6
4.2	48	30	4,475	179	23	7	14	50	6
4.5	72	40	7,550	224	30	7	12	44	7
5.0	*77*	*43*	*9,580*	*196*	*31*	*7*	*12*	*43*	*7*
5.7	74	40	11,480	218	34	7	10	43	6
6.7	67	41	13,600	324	37	6	9	42	6
			Bladen Sandy Loam						
4.2	11	9	392	112	11	6	21	57	5
5.1	68	30	1,174	151	24	7	15	47	7
6.4	*64*	*30*	*1,900*	*157*	*30*	*7*	*13*	*42*	*8*
7.0	34	29	2,800	184	32	6	12	43	7
7.6	25	23	4,700	313	32	6	12	44	6
			Norfolk Fine Sand						
5.0	16	12	224	112	8	6	21	58	7
5.1	32	24	392	128	19	7	21	45	8
5.2	46	25	560	101	22	7	18	45	8
6.6	*59*	*33*	*1,120*	*90*	*31*	*8*	*18*	*35*	*8*
7.1	69	30	1,453	195	36	7	15	34	8

[1]Mean pH before and after crop grown.
[2]Expressed in grams per pot (2 gallon size).
[3]Expressed in pounds CaO per 2,000,000 pounds soil.
[4]Obtained by totaling the milliequivalents of each element in a gram of dry plant material and calculating the percentage of each present.

PLANT ANALYSIS

These analyses are based on the chemical equivalents of the nutrients in one gram of plant material. It is noted that when the calcium supply of the soil was low the absorption by the plant was very low, but when the supply was high the absorption was high. The absorption of magnesium was quite uniform over all pH values in the soils. This was due to the fact that the supply of magnesium was fairly con-

stant and adequate for plant growth. Futher, the plants showed no tendency to absorb more magnesium than was actually utilized, since at low pH values magnesium was leached in a similar quantity to that which was absorbed by the plants at high pH values. While the supply of potassium was similar at all pH values, the absorption per gram of plant material was about twice as great at low pH values as at high pH values. Aluminum toxicity was, no doubt, directly responsible for the poor growth at the low pH values, but potassium was absorbed in excess of that actually utilized where the calcium supply was low. The nitrogen absorption took a similar trend to the potassium, but not quite so pronounced while phosphorus was quite constant. From this one would surmise that the balance of calcium, potassium, and nitrogen in these soils was very important for maximum crop production.

TABLE II—Total Nutrients Removed by Lima Bean Crop

Mean pH of Soil	Total Milliequivalents Absorbed				
	Calcium	Magnesium	Potassium	Nitrogen	Phosphorus
		Portsmouth			
3.9	5.62	3.48	10.23	33.72	3.03
4.2	33.41	10.64	20.67	74.20	10.03
4.5	56.60	12.94	21.83	80.96	13.35
5.0	59.70	14.08	22.19	82.70	12.80
5.7	63.60	12.90	19.36	79.90	11.69
6.7	72.49	12.36	17.70	84.00	11.52
		Bladen			
4.2	5.08	2.97	9.50	26.80	2.46
5.1	34.10	10.17	21.54	65.80	9.86
6.4	43.50	10.27	19.63	61.00	10.88
7.0	47.80	9.35	17.23	64.20	9.64
7.6	39.90	7.43	15.31	55.65	8.35
		Norfolk			
5.0	4.94	3.33	12.64	34.15	3.91
5.1	17.99	6.32	19.91	43.25	8.26
5.2	21.40	6.87	18.31	44.30	8.15
6.6	38.65	9.34	22.68	43.30	9.34
7.1	41.25	7.66	17.40	40.10	9.73

Nutrient Balance

The figures in Tables I and II show that at the pH value of maximum crop production the soil carried a desirable nutrient balance for the crop grown. These data indicate that around pH 5.0 a desirable combination of nutrients was found in the Portsmouth soil for the growth of lima beans. Upon analyzing the soil 9,580 pounds of replaceable lime per 2,000,000 pounds of soil were found, whereas only 380 pounds of potash, 220 pounds of magnesium, and a few hundred pounds of phosphorus and nitrogen were present. At pH 6.7, 13,600 pounds of lime were present with only approximately the same quantity of other nutrients as at pH 5.0. Assuming the calcium, leached and

plant-absorbed, as the influencing ion there was almost twice as much calcium in the soil solution at 6.7 as at 5.0 pH, whereas, there was very little change in the concentration of the potassium ions. For the Bladen soil the most desirable combination of nutrients was found between 5.1 and 6.4 pH. The replaceable calcium oxide was 1900 pounds per acre at pH. 6.4 and 4,700 at 7.6, and again, the leaching of calcium was practically doubled at the higher pH value. Here again the potash was 382 and magnesium 200 pounds per 2,000,000 pounds of soil. The Norfolk soil at pH 6.6 gave a good yield with a similar proportion of nutrients to the good yielding values in the Portsmouth and Bladen soils. While the ratios of calcium-potassium-nitrogen found in the plant were not absolutely constant for the three soils at the pH value of best yield they fell within the broad limit of Ca 2 to 3; K, 1; and N, 3 to 4. The pH values of the soils were not varied at close enough intervals to ascertain the exact optimum for these conditions. They do show, however, that there is a limit beyond which these soils should not be limed for maximum crop production, (Ehrenberg's "Potash Lime Law"). These data indicate that by raising the quantity of nutrients in the soil other than calcium (with particular emphasis on potash) the upper limits of the optimum pH range for growth may be raised.

Tests for Nutrients in Conducting Tissue as Indicators of the Nutritional Status in Horticultural Crops[1]

By E. M. EMMERT, *University of Kentucky, Lexington, Ky.*

RECENTLY, rapid tests on the plant have been proposed as a means of determining the nutritional status in plants. Earlier papers (1, 2) present literature reviews, methods, and results of these tests. It appears that these tests are reliable enough to have technical value and, on account of their simplicity and rapidity, it seems that they may prove to be practical for use on commercial plantings.

The solution for testing is obtained by extracting mature conducting tissues, usually the large portion of mature leaf petioles next to the lower main stem or the lower main stem itself. Ten cc of 2 per cent acetic acid is added to 1 to 5 (depending on the nutrient concentration) grams of chopped tissue as it is being triturated thoroly with a little phosphate-free charcoal in a mortar, and the extract is then filtered. The nitrate, soluble nitrogen and phosphate tests of this extract have been described. (1) (2).

RESULTS OF TESTS ON VARIOUS CROPS

Snap Beans:—This year the late plantings of beans on the Station Farm did not yield well despite plenty of rain. Our early plantings also did not yield well but we attributed the difficulty to drouth. However, the failure of the late planting could not have been due to drouth. It was observed that some beans planted at the same time, on poorer land and not cultivated much, gave heavy yields despite the fact that the season was the same on them as on the others. Tests on these two plots of beans gave the results shown in Table I. The result of heavy manuring is shown also. The results show that high nitrogen tends to throw beans into a permanent vegetative state with production of vines at the sacrifice of yield of beans.

It appears that the ratio of soluble N to phosphorus (N/P) should be between 1 and 3 at maturity, for good yields. If the phosphate could be increased in the plant a large amount of soluble N might not cause the vegetative tendency to such a great extent.

Lima beans:—Lima beans grown in the same soil types as the snap beans, referred to above, with the same seasonal conditions, showed even wider differences in set of pods and yields with the different soils. Tests on lima beans gave results shown in Table I. The vegetative tendency is even more marked in lima beans, probably because they take longer to mature than snap beans. The tests showed that the ratios for good yield should be lower than those for snap beans, from 0.5 to 1.) at maturity and as low as 0.21 in late maturity. The lima bean seems to maintain a higher normal level of phosphorous than the snap bean. The vegetative tendency of lima beans has previously been shown associated with high soluble N (2).

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[1]The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

TABLE I—RESULTS OF CONDUCTING TISSUE TESTS ON BEANS
(Analyses Expressed as P.P.M. of Green Tissue)

Crop and Soil	Soluble N	Phosphate P	$\frac{N^*}{P}$	Yield per 100 Ft. of Row (Pounds)	Notes
Snap beans on rich soil in August	832	160	5.2		Beans were not ready to pick until over a week after testing. Vines were large and leafy.
	556	73	7.6	5	
	456	133	3.4		
Snap beans on poor soil in August	200	67	3.0		Beans were ready to pick at the time of testing. Vines were rather small.
	180	80	2.2	40	
	180	100	1.8		
Snap beans (August) manured heavily	950	75	12.7	Light	No definite yields were taken.
Snap beans, no manure (August)	550	150	3.7	Fairly heavy	No definite yields taken.
Lima beans on rich soil in August	476	294	1.6		Samples were taken when vines were quite mature and some beans ready to pick first of August.
	456	294	1.5	0	
	476	267	1.8		
Lima beans on rich soil in September	332	200	1.7		Some beans tested in September after part of the crop had been harvested.
	416	178	2.3	0.25	
Lima beans on poor soil in August	—	266	—		
	180	266	0.7	4	
	186	230	0.8		
Lima beans on poor soil in September	90	320	0.28	6	
	83	400	0.21		
Lima beans heavily manured	454	67	6.8	Practically no beans	Very large, leafy vines. Samples taken when vines were young.
Lima beans, no manure	314	160	2.0	Heavy yield	Medium sized, highly productive vines.

$^*\frac{N}{P}$ = soluble N ÷ phosphate P.

NOTE: The samples tested were taken from different plants in different parts of the same planting.

TABLE II—RESULTS OF CONDUCTING TISSUE TESTS ON CABBAGE, CORN AND PEACHES
(Analyses Expressed as P.P.M. of Green Tissue)

Crop	Soil	Soluble N	Phosphate P	N/P	Notes
Cabbage	Rich upland known to be high in phosphorus	1000	200	5	Starting to head. Medium petioles.
Cabbage	Medium rich bottom	1100	80	14	Starting to head. Medium petioles.
Cabbage	Medium rich bottom	832	34	24	Starting to head. Medium petioles.
Cabbage	Medium rich bottom	556	89	6	This plant was yellowish looking.
Cabbage	Very rich bottom	2500	25	100	Large heads formed. Petioles large.
Cabbage	Poor clay	75	50	1.5	Small plants and heads. Petioles small.
Corn	Rich bottom	832	21	40	Largest diameter of stalk 2½ cm.
Corn	Medium rich	662	24	28	Largest diameter of stalk 2½ cm.
Corn	Poor clay	258	29	9	Largest diameter of stalk 1 cm.
Peaches	In sod	62	333	0.19	Petioles of leaves taken in late July.
Peaches	In sod	55	350	0.16	Petioles of leaves taken in late July.
Peaches	In sweet clover	80	89	0.90	Petioles of leaves taken in late July.
Peaches	In sweet clover	84	103	0.82	Petioles of leaves taken in late July.

TABLE III—RESULTS OF CONDUCTING TISSUE TESTS ON LETTUCE AND TOMATOES IN THE GREENHOUSE

Crop and Soil	Soluble Nitrogen*		Phosphate Phosphorus		N/P Ratio		Yield per Plant (Ounces)		pH of Soil (Average)
	Fall Crops	Spring Crops	Fall Crops	Spring Crops	Fall Crops	Spring Crops	Fall Crops	Spring Crops	
Lettuce									
Red clay	417 320†	498 149	22 40	19 21	19 8	26 7	39	22	5.8
Sandy soil	419 545	760 147	41 109	53 32	10 5	14 5	43	22	7.5
Brown silt loam	555 650	805 272	35 177	70 42	16 4	12 6	86	31	6.2
Black silt loam	1049 545	1158 638	96 226	193 143	11 2	6 4	119	58	6.0
Tomatoes									
Red clay	190 32	50 —	45 58	25 —	4.2 0.6	2.0 –	13	23	5.3
Sandy soil	212 34	41 —	43 26	286 —	5.0 1.3	0.14 –	23	23	7.4
Brown silt loam	447 25	89 —	130 156	133 —	3.4 0.2	0.67 –	34	38	6.0
Black silt loam	645 43	348 —	280 260	167 —	2.4 0.2	2.1 –	50	62	6.1

*Nitrate nitrogen in the tomatoes.
†First column of figures represent tests in the early stages of the crop. Second column of figures represent tests in the late stages of the crop.

It should be noted that the ratio of N to P may be much larger in the young growing plants without harm but if the ratio does not decrease with age the tendency is to delay maturity and reduce yields. Further studies to determine the best ratios at various stages of growth would be well worth while.

Cabbage:—Table II shows results from tests on the portion of the petioles of cabbage next to the main stem. It was apparent that the concentration of soluble nitrogen was the important factor here. Even when phosphate dropped very low, growth was good if plenty of nitrogen was present. A N/P ratio of 100 did not reduce the yields of cabbage but enhanced leaf growth, resulting in a production of very large heads. The petioles in this case were very watery and brittle, while the petioles on the stunted plants with a ratio of 9, on the poor clay, were tough and stringy. The difference between 2500 p.p.m. of soluble nitrogen in plants on the rich bottom and 75 p.p.m. in plants on the red clay hill undoubtedly is the biggest factor in causing the extreme difference in type of growth. The favorable effect of high soluble nitrogen on cabbage has been previously noted (2).

Corn:—The same relationship was found with corn as with cabbage. The results are presented in Table II. Much larger stalks were present in the bottom land. No records of yields were taken.

Peaches:—Table II also shows results with peaches. The differences in soluble nitrogen are not so marked here as with annual crops. Phosphate, however, shows even greater differences. The tests have not been tried very much on trees, but the fact that organic substances do not interfere in the soluble nitrogen test makes it possible to use it where nitrate nitrogen tests do not work well; namely, in the presence of amygdalin and other glucosides and other organic substances found in trees.

Lettuce:—Table III shows wide differences in nutrients present in the midribs of lettuce grown on different soil types. The correlation of yield, with both soluble nitrogen and phosphate phosphorus, is good in the fall crop. The correlation is fair in the spring crop. The yield was stunted in the sandy soil because heating pipes caused it to dry out excessively.

Tomatoes:—Table III also shows the same order of differences in nutrients present in tomato petioles grown on the same soil types as lettuce. The correlations are about the same as with lettuce, with the exception that much lower N/P ratios are favorable to good production of tomato fruits. The stunting effect of the drying out from heating pipes is again shown here in the spring crop. The drying out caused a lowering of nitrogen and an accumulation of phosphorus in tomatoes. It will be noted that the yields in the spring crop increased in spite of a drop in nutrients. This likely was partly due to the lower N/P ratios in the spring, altho some of the increase undoubtedly was due to the increased length of day.

Summary

Soil types or manure additions which maintained high soluble nitrogen in the plant tissues caused both snap beans and lima beans to make an excessive vegetative growth resulting in small yield. If the

soluble nitrogen-phosphate phosphorous ratio (N/P) were kept low it appears that this vegetative tendency might be overcome even in rich soil. Cabbage and corn, however, did not appear to require such low N/P ratios. High and low ground and soil type caused variations from 2500 p.p.m. to 75 p.p.m. with corresponding extremes in yield and type of growth. The soluble nitrogen test worked satisfactorily on peach petioles because interfering organic compounds were destroyed previous to the addition of phenoldisulfonic acid. Tomatoes and lettuce showed good correlation between nutrient concentrations and yield. Tomatoes showed that a low N/P ratio was favorable to good yields, while lettuce gave good yields at higher ratios.

Results of the plant tests on corn show that it is not as likely to be thrown out of production by high soluble nitrogen as are beans and tomatoes.

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Effects of Magnesium Deficiency in the Soil on the Yield, Appearance and Composition of Vegetable Crops

By R. L. Carolus, *Virginia Truck Experiment Station, Norfolk, Va.*

PREVIOUS reports (1, 2, 3) have discussed the causes and nature of magnesium deficiency in plants as induced by a deficiency of this element in the soils of the Atlantic Coast.

During 1933, response to magnesium treatment was observed in 18 of the more important crops of this section. The plants were grown on a soil whose previous crop indicated it to be deficient in magnesium. The area was divided into six plats, three serving as checks. The treated portions received 2,000 pounds of dolomitic limestone (17 per cent MgO) per acre and 2 per cent soluble magnesia from kieserite in all fertilizer applied. The check plats were limed with calcium lime to the same reaction as the treated plats and fertilized with material containing no magnesium.

The yields of most of the crops grown, arranged in the order of their response to treatment, are given in Table I. Increases in yield were obtained of from 1 to 92 per cent due to magnesium applications to the soil. The effect of treatment on the intake of magnesium, by the portion of the plant on which yield was recorded, is also given.

The characteristic appearance of the foliage of each crop is stated in the paragraph beneath the table. In general, yellowing between veins, brittleness, and marginal raggedness were the most noticeable features in the foliage of magnesium deficient plants. These symptoms usually appear earliest on the lower leaves and may or may not extend to the upper foliage.

In Table II the magnesium, calcium, and nitrogen composition of four typical crops grown on the described area is shown. Application of magnesium to the soil had a more pronounced effect on the magnesium content of the plant than on yield. In cucumbers, for example, the magnesia content of the lower leaves increased to 586 per cent of the untreated but in terms of the untreated plant the yield increase in total green weight of foliage was only 139 per cent and was 144 per cent in pounds of fruit produced. The calcium content of the plants showed no definite trend except in the fleshy roots and fruits. In these portions calcium was substituted for magnesium when the latter element was deficient in the soil on which the plants were grown. Lower leaves contained more calcium and magnesium than the other portions of the plant. Upper leaves contained more nitrogen than any other portion. The stems and petioles did not fluctuate as widely in per cent magnesia with treatment as did the other portions of the plant.

In Table III the yields, soil reaction, and percentage of MgO and CaO in potato plants grown on plats treated with six kinds of lime are given. The hydrated magnesium lime and the dolomitic limestone caused an increase of over 75 per cent in the MgO content of the plants over that of others from the untreated area. The decrease in the

MgO content of the plants on the plats receiving calcium limes, over those on the unlimed area, was proportional to the availability to the plants of the CaO contents of the limes, i. e., hydrated calcium lime depressed the MgO absorption of the plant to the greatest extent. This

TABLE I—EFFECT OF MAGNESIUM ON THE YIELD AND COMPOSITION OF TRUCK CROPS

Rank*	Crop	Crop Yield (Pounds per Acre)				Increase in MgO Content Over Untreated (Per Cent)
		Treated	Untreated	Difference	Per Cent Difference	
1	Turnip, roots	5,650	2,950	2,700	+ 92	60
2	Sorghum, foliage	17,600	10,250	7,350	+ 72	123
3	Beet, plants	3,175	1,875	1,300	+ 69	49
4	Potato, tubers	16,500	9,900	6,600	+ 67	1900 (foliage)
5	Pea, plants	1,883	1,229	654	+ 53	85
6	Pepper, fruit	9,915	6,560	3,355	+ 51	42
7	Cucumber, fruit	23,235	16,178	7,057	+ 44	36
8	Squash, foliage	11,500	8,900	2,600	+ 29	95
9	Radish, roots	4,725	3,700	1,025	+ 28	20
10	Soybean, foliage	20,275	16,450	3,825	+ 23	130
11	Snap bean, pods	7,575	6,225	1,350	+ 22	48
12†	Cabbage, foliage	13,800	12,525	1,275	+ 10	33
13	Eggplant, fruit	19,925	18,100	1,725	+ 10	30
14	Carrot, roots	5,500	5,150	350	+ 7	178
15	Corn, ears	3,498	3,408	90	+ 3	186 (foliage)
16	Onion, bulbs	5,364	5,328	36	+ 1	29

*Arranged in the approximate order of their yield response to magnesium treatment.
†Early crop. Later crops have been complete failures on the same field.

CROPS GIVEN IN TABLE I ARRANGED IN THE ORDER OF THE COMPARATIVE EASE OF DETECTION OF MAGNESIUM DEFICIENCY IN THEIR LEAVES

Crop	Characteristic Type of Injury
1. Pepper......	Yellowing of interveinal areas, starting at tip. Brittleness and upward curl of leaves.
2. Potato......	Yellow-brown mottling of central portion of leaf. Brittleness and downward curl of leaves.
3. Turnip......	Yellowing and brown spotting, starting at margin. Edges become brown and ragged.
4. Cucumber...	Yellowing of entire interveinal area. Veins stand out green, edge ragged.
5. Radish......	Same as turnip, but less pronounced.
6. Cabbage....	Formation of large yellowish patches with brown spots between the veins.
7. Corn.......	Interveinal areas yellow completely; edge and tip turn brown.
8. Snap bean...	Leaf lighter green in color. Brown spotting follows the veins.
9. Squash.....	Similar to cucumber, but not as pronounced.
10. Soybean....	Interveinal mottling in some cases, browning of the veins in others.
11. Pea........	Browning of the tips of the leaves. Early dying of foliage.
12. Onion......	Dying back of tips, early dying of foliage.
13. Carrot......	Lightening of foliage color, brown spotting of tips of leaves.
14. Eggplant....	Lightening of foliage color in large areas in the center of the leaf.
15. Sorghum....	Dying back of tips, reddening and yellowing of entire margin of the blade.
16. Beet........	A reddening of the foliage and a lack of growth.

TABLE II—THE INFLUENCE OF MAGNESIUM APPLICATION ON THE COMPOSITION AND YIELD OF SNAP BEANS, CUCUMBERS, PEPPERS AND TURNIPS

Composition on Dry Weight Basis	Portion of Plant	Magnesium Application	No Magnesium Application	Per Cent of Untreated Found in Treated Plant
	Snap Beans			
MgO (Per cent)....	Leaflets	0.81	0.17	467
	Stems and petioles	0.17	0.18	96
	Fruit	0.48	0.32	148
CaO (Per cent)....	Leaflets	3.73	3.00	125
	Stems and petioles	2.19	1.78	123
	Fruit	0.71	1.06	68
N (Per cent).......	Leaflets	3.99	3.32	120
	Stems and petioles	1.56	1.52	103
	Fruit	3.43	3.40	101
Yield*............	Foliage	4410	3771	117
	Fruit	7575	6225	122
	Cucumbers			
MgO (Per cent)....	Upper leaves	0.77	0.36	212
	Lower leaves	1.28	0.21	586
	Stems	0.76	0.38	201
	Fruit	0.59	0.43	136
CaO (Per cent)....	Upper leaves	2.34	2.55	92
	Lower leaves	6.42	5.53	116
	Stems	2.12	2.71	78
	Fruit	0.71	0.74	95
N (Per cent).......	Upper leaves	4.79	4.48	107
	Lower leaves	3.69	3.23	114
	Stems	3.71	3.50	106
	Fruit	3.65	4.12	89
Yield*............	Foliage	4850	3500	139
	Fruit	23235	16178	144
	Peppers			
MgO (Per cent)....	Leaves	0.82	0.18	447
	Fruit	0.31	0.22	142
CaO (Per cent)	Leaves	3.55	2.71	131
	Fruit	0.31	0.46	68
N (Per cent).......	Leaves	3.95	4.15	95
	Fruit	3.83	3.53	109
Yield*............	Fruit	9915	6650	151
	Turnips			
MgO (Per cent)....	Blade	0.51	0.29	177
	Petiole	0.32	0.22	146
	Root	0.40	0.25	160
CaO (Per cent)	Blade	2.49	3.36	74
	Petiole	3.47	4.90	71
	Root	1.70	2.51	68
N (Per cent)......	Blade	3.69	3.98	93
	Petiole	3.74	3.97	94
	Root	3.97	4.20	95
Yield*............	Foliage	6625	3950	168
	Roots	5650	2950	192

*In pounds per acre.

lime was followed in the order of their depressive effects on magnesia absorption, by limestone, oyster shell lime, and Falling Springs lime. MacIntyre (4) has explained this phenomenon in that the addition of high calcic liming material exerts a "protective effect" upon the natural supplies of magnesium, due to the fact that the alkaline calcium materials repress the hydrolysis of the magnesic complexes of the soil. The deficiency symptoms in the foliage were most noticeable on plants grown on the untreated check plats. As these plants contain more magnesium than those grown on the calcium lime treated plats, the utilization of some MgO substituting for the plant's paucity in CaO must be offered as an indirect reason for the deficiency symptoms manifested. This substitution of MgO for CaO probably causes a shortage of the former for the adequate performance of its own physiological functions.

TABLE III—THE EFFECT OF VARIOUS LIMES ON THE SOIL pH, MgO AND CaO CONTENT OF POTATO PLANTS (1934)

Treatment in Terms of 2000 Pounds of $CaCO_3$ and $MgCO_3$ per Acre (Applied 1932)	Soil pH	Yield (Barrels per Acre)	Chemical Composition of Plant*	
			MgO	CaO
Check (untreated)	4.05	111	0.83	1.48
Hydrated (Ca)	5.05	141	0.59	2.42
Hydrated (Mg)	4.80	131	1.41	1.74
Check (untreated)	4.40	108	0.87	1.75
Falling Springs (Ca)	4.70	126	0.70	2.21
Oyster Shell (Ca)	5.20	147	0.66	2.08
Check (untreated)	4.30	89	0.89	1.51
Dolomite (Mg)	4.80	149	1.52	1.83
Limestone (Ca)	4.65	130	0.65	2.40

*Expressed in percentage of the dry weight of the tops.

In Table IV the MgO, CaO, and N composition is given of apical and basal portions of three types of cabbage leaves taken from a field showing magnesium deficiency symptoms. Deficient leaves contained

TABLE IV—A COMPARISON OF THE COMPOSITION OF MAGNESIUM AND NITROGEN DEFICIENT CABBAGE LEAVES

Description of Leaves	Portion of Leaves	MgO* (Per cent)		CaO* (Per cent)		N* (Per cent)	
Normal leaf	Tip	0.126	—	3.92	—	3.39	—
Green	Base	—	0.274	—	3.64	—	3.44
Per cent of normal composition		100	100	100	100	100	100
Magnesium deficient leaf	Tip	0.061	—	3.46	—	2.99	—
Brownish-yellow mottling	Base	—	0.153	—	3.74	—	3.30
Per cent of normal composition		48	56	88	1.03	88	96
Nitrogen deficient leaf	Tip	0.198	—	5.57	—	1.63	—
Reddish-purple coloring	Base	—	0.295	—	6.76	—	2.42
Per cent of normal composition		157	108	142	186	48	70

*Composition on the dry weight basis.

only 48 per cent as much MgO in their tips and 56 per cent as much MgO in their basal portions as those from normal appearing plants. The calcium and nitrogen contents of magnesium deficient leaves were a little lower at the tips but approximately the same as that of normal plants in the basal portion. Plants in this field lacking an adequate supply of N had reddish purple tipped leaves. Leaves from these plants contained only 40 per cent as much N in their tips and 70 per cent as much in their basal portions as normal plants. Plants showing this nitrogen deficiency trouble are considerably higher in MgO and CaO than normal plants. Some plants with symptoms of magnesium deficiency and other plants exhibiting nitrogen deficiency grow together in the same field in many instances but are quite easily distinguished by their external appearance and internal composition.

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Reduction of Daylight Period on Asters

By Alex Laurie, and E. W. McElwee, *Ohio State University, Columbus, O.*

ASTERS grown under tobacco cloth may be brought into bloom earlier by a reduction of the daylight period from 5 p.m. to 7 a.m. by shading with black sateen cloth as described by Laurie and Poesch (1) for chrysanthemums. The results and conclusions of the 1934 tests are given below (Table I).

TABLE I—Effect of Reduction of Daylight Period of Asters by Cloth, 1934

Variety*	No. Plants per Plot	Date Shaded	No. Plants Wilted	Date First Cut	Date Last Cut	Days First to Last Cut	Ave. Number Flowers per Plant	Ave. Stem Length (Inches)	Ave. Diameter (Inches)
Royal Purple	21	6/20	—	7/6	7/19	14	13	10	2
	21	6/27	—	7/6	7/23	18	16.6	12.5	2.6
	21	7/4	—	7/6	8/1	27	11.1	14.8	2.3
	21	Check	—	7/6	8/8	33	14.3	16.6	2.3
Imbricated Rose (Pompon)	21	6/20	3	7/6	7/23	18	19.4	9.8	1.3
	21	6/27	15	7/11	8/1	22	19.6	11.1	1.1
	21	7/4	—	7/11	8/1	22	19	13	1.3
	21	Check	2	7/11	8/8	29	17	13.6	1.5
Royal Shell Pink	21	6/20	—	7/15	8/3	20	15.7	14	2.6
	21	6/27	1	7/19	8/3	16	15	16	2.5
	21	7/4	—	7/19	8/8	21	11.5	15.8	2.7
	21	Check	—	7/26	8/14	20	9	21.7	3.3
Royal White	21	6/20	1	7/19	8/3	16	11.6	14	2.4
	21	6/27	—	7/19	8/3	16	11.1	16.2	2.3
	21	7/4	1	7/26	8/8	14	9	17.2	2.5
	21	Check	—	8/1	8/17	17	8	22	2.7
Ball's Deep Rose	21	6/20	1	7/15	7/23	9	10.5	15	2.5
	21	6/27	4	7/19	7/30	12	10	18.2	2.3
	21	7/4	—	7/26	8/3	9	8	19	2.5
	21	Check	—	7/28	8/11	15	8.2	25	2.9
American Branching Azure Blue	28	6/20	—	7/15	8/8	25	8.4	17.3	2.4
	21	6/27	—	7/15	8/8	25	10	20.4	2.5
	28	7/4	2	7/28	8/14	18	7	21.3	2.7
	28	Check	—	8/1	8/17	17	6.3	28	3
Crego Deep Pink	28	6/20	1	7/15	7/30	16	10.6	16	3
	21	6/27	1	7/23	7/30	7	9	17.1	2.7
	28	7/4	1	7/23	8/8	16	7.2	21	3
	28	Check	—	7/28	8/14	18	5.5	23.2	3.3

*All varieties were planted May 18, 1934.

Conclusions

1. An early reduction of the daylight period decreased the length of flower stem. All varieties tested showed a successive increase in stem length when the reduction of daylight period began 5, 6, and 7

weeks after planting. The average increase in stem length, of all varieties tested, of the check over reduction of daylight period 5 weeks after planting was 7.6 inches.

2. Late-flowering varieties showed a greater response to the reduction of daylight period than early-flowering varieties. The variety Royal Purple gave the first cut July 6 regardless of when the reduction of daylight period began. American Branching Azure Blue gave the first cut July 15 when the daylight period was reduced 5 weeks after planting and the first cut August 1st when given normal treatment.

3. An early reduction of the daylight period showed a slight decrease in diameter of flower.

4. A reduction of the daylight period beginning about 7 weeks after planting and lasting until color showed in the flower, on asters planted about the middle of May seems to give the optimum results as to size of flower, number of flowers, length of stem.

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A Method for Studying Nutrient Deficiencies in Greenhouse Crops

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A SERIES of tests were started in 1931 at the Ohio State University to determine accurately the nutrient deficiency symptoms in the more important greenhouse crops to serve as a guide in diagnosing the physiological troubles of greenhouse crops.

The present method is an adaptation of the Shives and Stahl Method (1). It is one that is satisfactory for handling a large number of crops under controlled conditions more nearly approaching actual soil conditions than either water or sand cultures in which the nutrient solution is applied intermittently. The plants grown in the constant renewal sand culture method are superior in every respect to those grown by the intermittent method. This fact has also been previously noted by Allison and Shives (2).

METHODS

The apparatus used in this experiment is similar to the one reported by Shives and Stahl (1), except that a gravity feed from the reservoir is used in place of a siphon and sand in place of water. The apparatus consists of a 3-liter covered stone jar reservoir with a ¾-inch hole near the bottom fitted with a one-hole rubber stopper and a 1¼-inch piece of ordinary glass tubing. The outlet is connected to a glass T with a 1¼-inch length of rubber tubing and a screw regulative clamp. The glass T is connected by rubber tubing to two 4-inch lengths of 0.5 mm glass capillary tubing, giving two outlets from each reservoir. When the apparatus is set up the reservoir is placed slightly higher than the culture pot and the capillary outlets are rested on the edge of the culture pot. The flow is regulated to one drop of solution every 5–7 seconds which delivers about ½ liter of solution every 24 hours through each outlet. This amount is sufficient to give a constant drip from a 6-inch pot.

The plants were started in ordinary greenhouse soil and transferred to the sand cultures when they were ready for transplanting. All of the soil was carefully washed from the roots and the plants potted in a mixture of ½ medium coarse quartz sand and ½ Diamond Sand Blast sand. The sand used was washed with weak hydrochloric acid solution and distilled water. This mixture gives a uniform distribution of solution throughout the pot without becoming water-logged. The plants were potted in a 6-inch pot having a ¼-inch drain in the bottom covered with fine copper mesh and glass wool.

The nutrient solutions used in this experiment were as shown in Table I.

The nutrient solutions were regulated to a pH 6 with N/10 sulphuric acid (H_2SO_4) to give a uniform acidity to all treatments. The sand cultures were leached every week with 500 cc of distilled water to prevent injury from high soluble salt concentration.

TABLE I—NUTRIENT SOLUTIONS USED

Chemical	Partial Volume Molecular Concentration			
	Complete	—Nitrogen	—Phosphorus	—Potassium
KH_2PO_4	.00633	.00633	——	.00633
$CA(NO_3)_2 \cdot 4H_2O$	.00584	——	.00584	.00584
$MgSO_4 \cdot 7H_2O$	.0023	.0023	.0023	.0023
$CaCl_2 \cdot 2H_2O$	.0029	.0029	.0029	.0029
$NaH_2PO_4 \cdot H_2O$	——	——	——	.00633
$MnSO_4$	.00001	.00001	.00001	.00001
H_3BO_3	2 cc of a 1 per cent solution per 17 liters of stock solution			
$Fe_2(SO_4)_3$	25 cc of a 1 per cent solution per 17 liters of stock solution			

RESULTS

Most of the crops tested have shown rather definite nutrient deficiency symptoms and these deficiences in the poinsettia (Euphorbia pulcherrima), sweet pea (Lathyrus odoratus), snapdragon (Antirrhinum majus) and Cineraria (Cineraria cruenta) are listed as follows:

Complete solution:—Normal growth in all cases with dark green color and no loss of leaves.

Minus Nitrogen:—

Poinsettia—Pronounced dwarfing of the plants with a uniform yellowing of all leaves, the older leaves curling and dropping when completely yellow.

Sweet Pea—Pronounced dwarfing of the plants with the leaves fading to light yellow and white. Some leaves are almost devoid of chlorophyll. Slight dropping of old leaves.

Snapdragon—Pronounced dwarfing of the plants. All leaves show a rusty brown color and do not develop new shoots after pinching.

Cinerarias—Plants dwarfed in growth with all leaves slightly yellow in color.

Minus phosphorus:—

Poinsettia—Pronounced dwarfing of the plants with the older leaves turning yellow and dropping before yellowing is complete. Defoliation continued until only the very young leavès remain.

Sweet Pea—Normal growth with only a slight yellowing of old leaves and no loss of foliage.

Snapdragon—Pronounced dwarfing of the plant with the old leaves showing a decided purplish color.

Cineraria—Plants almost normal in growth. The leaves are yellow around the margin and between the veins with no loss of foliage.

Minus potassium:—

Poinsettia—Plants only slightly retarded in growth. The older leaves turn yellow and finally brown around the margins and between the veins with the veins remaining green. They remain on the plant until completely dry. The young leaves retain the normal green color.

Sweet Pea—Plants are dwarfed to about one-half the normal size. Leaves turn yellow on margins and drop early. The young leaves turn a light green color,

Snapdragon—Plants slightly dwarfed with the old leaves yellow throughout and the young leaves yellow around the margins and between the veins. The veins on the young leaves retain the normal green color.

Cinerarias—Plants slightly yellow with the old leaves slightly yellow throughout and the young leaves with a definite purple margin and light yellow centers.

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Evidence that Some Plant Roots Give off Organic Acids

By JOHN C. RATSEK, *Cornell University, Ithaca, N. Y.*

THERE is much disagreement among investigators on the question of acid secretion by roots of plants. The evidence so far obtained, indicates that only carbonic acid is secreted from plant roots under normal conditions. Many workers believe that this carbonic acid secreted from the roots, together with carbonic acid resulting from bacterial action in the soil, has sufficient solvent action to dissolve from the soil everything needed by the plant. Other workers disagree and believe that carbonic acid alone is not enough to dissolve these chemicals and suggest that organic acids from the roots of plants may be a factor. An excellent and complete discussion bibliography is given by Thomas (1).

Incidental to a nutritional problem, it became necessary to determine if plant roots might not secrete an organic acid during active growth. Organic acids generally are difficult to detect in small quantities, and oxalic acid was chosen for this work because of the slight solubility of its salt, calcium oxalate, in water.

Knudson's solution B (2), modified by substituting sodium nitrate for calcium nitrate and adding no iron phosphate, was employed. This was divided into five lots and calcium as calcium chloride was added to give the following concentrations: 1, 10, 100, 500, and 1000 p.p.m. Each of these was divided into four parts. No iron was added to one part and the pH adjusted to 5.5. A second was adjusted to pH 5.5 and 2 p.p.m. of iron added as ferric chloride. The third and fourth parts were adjusted to pH 7.2 and one treated with iron as outlined above. In addition to the above cultures, solution B with and without iron, adjusted to pH 5.5 and pH 7.2 and containing about 250 p.p.m. of calcium as in the third part, was used.

Strips of ashless filter paper ½ inch wide and 5 inches long, were looped and pushed into 1 x 180 mm Pyrex culture tubes with the loop up. The culture solutions were carefully poured into the tubes so that the surface of the liquid was about ⅛ inch below the loop of the filter paper. Twenty to 25 cc of solution was necessary. The treatments were in duplicate. After plugging with cotton, the tubes were sterilized for 15 minutes at 15 pounds steam pressure. Seeds of *Oxalis repens* were sterilized in calcium hypochlorite solution and sown under sterile conditions on the loop of the filter paper. The seeds were allowed to germinate and grow in a shaded greenhouse until the first plants began to show a browning of the leaves. The plants and filter paper were then removed. The remaining solution was examined for calcium oxalate crystals and the plants were examined for chlorosis and amount of growth.

In the method employed to examine the solution for the crystals, the solution was well shaken, poured into centrifuging tubes, and centrifuged at 2000 r.p.m. The solid material remaining, was then washed with distilled water and centrifuged twice. A slide was made of this washed material and it was examined for calcium oxalate

crystals. Crystals when found, ranged from 6 microns square to 6–12 wide and 15–21 long. The crystals were compared with crystals formed by adding drop by drop very dilute oxalic acid solution to a dilute alkaline calcium chloride solution, and centrifuged and washed as before. They were further compared with crystals found in plants (3).

Table I shows the results obtained. In describing chlorosis the following terms are used: (a) "Little", a few of the leaves pale green; (b) "some", most of the leaves pale green and parts of one or two leaves white; (c) "much", several leaves white, and (d) "white", the whole plant white. The observations are recorded for two cultures unless otherwise indicated.

TABLE I—THE EFFECT OF CALCIUM CONTENT, IRON CONTENT, AND pH OF CULTURAL MEDIA ON THE GROWTH AND EXCRETION OF OXALIS ACID OF *Oxalis repens*

pH and Ca Concentration	Cultures with Iron			Cultures without Iron		
	Height (Ins.)	Chlorosis	Crystals	Height (Ins.)	Chlorosis	Crystals
pH 5.5						
1 p.p.m. Ca	1.00	little		.85	some	
10 p.p.m. Ca	1.50	little		1.40	some	
100 p.p.m. Ca	1.25	little	X	1.75	little	X
500 p.p.m. Ca	1.00	some		1.75	little	
1000 p.p.m. Ca	1.00	some		.25	white	
B-250 p.p.m. Ca	1.75	little	X	1.25	some	
pH 7.2						
1 p.p.m. Ca*	1.20	some		.25	white	
10 p.p.m. Ca	.45	much		.85	white	
100 p.p.m. Ca	1.80	little	X	.60	white	
500 p.p.m. Ca	1.75	none		.50	white	
1000 p.p.m. Ca	.75	much		.35	white	
B-250 p.p.m. Ca	1.85	some	X	.65	white	

*Only one culture because of infection in the second one.

DISCUSSION

Crystals were found only when the calcium content was 100 or 250 p.p.m. Where the calcium content was 1 and 10 p.p.m. subsequent analysis of the solution for calcium by the oxalic acid method showed no calcium present. This might explain the absence of crystals in these treatments on the basis that the root completely absorbed the calcium. A calcium test of the 100 p.p.m. concentration showed the presence of 15–25 p.p.m. of calcium still present in the solution at the completion of growth. In the 500 and 1,000 p.p.m. calcium cultures, the calcium present varied from 460 to 525 p.p.m. and 950 and 1,010 p.p.m., respectively. It would seem that where the calcium content is above 500 p.p.m., the oxalic acid is not secreted by the roots. This may be due to a change in permeability of the roothairs preventing the secretion of the acid, or it may be due to the interaction of calcium and oxalic acid within the plant in the presence of high concentration of calcium.

An examination of the growth of Oxalis as shown by height and by amount of chlorosis, shows that the best growth takes place in the medium ranges of calcium content where the crystals were found. It is possible that there may have been crystals in treatment where none were apparent, because several crystals had to be identified before they were considered as present. In the solutions of pH 7.2 and lacking iron, no crystals were found. It is possible that, because of lack of growth as shown in the table, not sufficient oxalic acid was formed in the plant to be excreted.

Inasmuch as the seeds were sterilized in calcium hypochlorite solution it is certain that some calcium was introduced into the culture solution with the seed. Just how much was introduced is not known for this factor was not taken into consideration until later when analyses for calcium were made and showed that in some cases there was an increase of calcium over the original amount.

A similar experiment using corn in flasks with like concentrations of calcium and a pH of 3.5, 5.5, and 7.2 was set up. No calcium oxalate crystals were found in any culture. The pH of all cultures of the alkaline group dropped to pH 4.9 to 5.7 and in most cases all the original calcium phosphate precipitate was redissolved. This may have been due to carbonic acid excreted by the roots, but it is doubtful if a concentration high enough to be effective could have been built up in the media and the possibility of the presence of organic acids suggests itself. Titration with potassium permanganate showed the presence of organic matter equal to .05 to .08 normal oxalic acid. There was no filter paper in these cultures for the seeds were germinated on floating blocks of paraffin.

Experiments are now under way in which all seeds used were sterilized with mercuric chloride. Calcium contents between 100 and 500 p.p.m. were also employed. The results may show more clearly the relation between calcium content of external media and the excretion of organic acids by roots.

Conclusions

The results of these experiments indicate that roots of some plants may excrete organic acids. They further indicate a relationship between calcium content of the external solution employed in these experiments and the excretion of organic acids.

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Some Factors Affecting Flower Bud Initiation and Development in the Chrysanthemum (*C. morifolium*)

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

CHRYSANTHEMUMS (*Chrysanthemum morifolium* Bailey) frequently fail to flower when grown in the field or greenhouse. Such a tendency is designated as "blindness." This so-called blindness may be classified under the three following headings: (a) Vegetative development with no flower bud production; (b) flower bud production at a much later date than is normal; and (c) normal flower bud production followed by a cessation or an abnormal development of the bud.

The variety Major Bonaffon was used in the experiments here reported, because it shows a tendency toward blindness more frequently than other disbudded varieties. The plants were grown in the greenhouse bench and two flowers allowed to develop on each plant. In addition the variety Natick, frequently reported to come blind, was also used and grown as a pompon. The plants were grown 7½ x 8 inches apart unless otherwise stated.

RESULTS

The effect of insect injury:—Many plants were examined in commercial establishments and tarnished plant bug (*Lygus pratensis* L.) injury was the most common cause of blindness. The insect pierces the terminal growing tissue of the plant, either in the vegetative or flower bud stage. This results in the termination of growth at that point. If the attack occurs early in the season, and the plant is still in the vegetative stage, lateral vegetative shoots develop below the injured point. If the flower bud has been selected and all lateral buds removed before the attack no further growth occurs and the flower bud ceases development. If the injury occurs after the flower bud is well developed, one side may mature, producing a malformed bloom.

The effect of the nitrogen concentration of the soil:—In 1933, using the variety Major Bonaffon, 30 plants were grown in each of 4 plots. They were benched from 3-inch pots June 16 and grown according to commercial practice until September 30, when ammonium sulfate was applied at the rate of 3, 5, and 7 pounds per 100 square feet of bench area (5 inches of soil). These treatments were repeated at weekly intervals until three applications were made.

Many plants were severely injured and some killed in the plots where 5 or 7 pounds of ammonium sulfate were applied but no blind growths occurred on the plants which survived. Many plants bloomed after the injury had become so great that the lower one-half to two-thirds of the foliage was dead.

This experiment was repeated in 1934, using the same variety but substituting sodium nitrate for ammonium sulfate at the rate of 2, 4, and 6 pounds per 100 square feet of bench area. The applications began August 23. Buds normally appear about September 5 on this

variety. No plants were killed by the treatments although some showed injury. No blind shoots occurred in any treatment.

The effect of distance of planting:—Using the variety Major Bonaffon in 1933 the plants were planted in the greenhouse bench 7½ x 8 inches, 6 x 6 inches, 6 x 4 inches, and 4 x 4 inches. All were grown two stems to a plant. No stem was blind in any treatment.

The effect of hardening and late planting:—To determine the effect on blindness of holding plants in small pots, thus permitting the wood to harden before planting, 30 plants were propagated March 15, 1933, for each of 4 plots. They were potted in 2-inch pots April 2. Two of the lots were shifted to 3-inch pots June 16, and two lots remained in 2-inch pots until the time of benching. One lot from each size of pot was benched August 24, and both remaining lots were benched September 26. All plants were extremely hard at the time of planting, due to the long time they had remained in small pots without feeding. Most of them had four to six leaves at the top of each branch at the time of planting and those planted September 26 had previously formed flower buds. No blind shoots appeared in any treatment.

The effect of late propagation and late planting:—Thirty cuttings of Major Bonaffon were taken August 30, 1933, and were benched from the propagating sand September 26. None of the plants bloomed in normal season and only eight of the 30 bloomed during 1933. Observations of these cuttings showed that stem elongation did not occur after the normal season of bloom of the variety. It is evident that short days prevented stem elongation and promoted flowering. A period of stem elongation is apparently necessary before flowering can occur and flowering resulted only where this stem elongation had taken place.

The effect of height, position, and time of the last pinch:—To determine the effect of the height, position, and time of pinching on blindness, plants of Natick were propagated March 20, 1934 and

TABLE I—EFFECT OF HEIGHT, POSITION AND TIME OF LAST PINCH ON BLINDNESS

Height, Date, and Location of Last Pinch	No. Plants	No. Terminal Growths	Terminal Growths Blind (Per cent)
Pinched to leave 4 joints			
August 1	10	74	0
Sept. 1	9	69	0
Sept. 15	8	70	68
Sept. 30	4	30	37
Top removed at joint			
Sept. 1	9	87	6
Sept. 15	10	80	15
Sept. 30	10	55	0
Top removed between joints			
Sept. 1	8	81	1
Sept. 15	10	96	8
Sept. 30	9	56	0

benched from 3-inch pots June 20. The stock of this variety was all blind in a commercial establishment in 1933. Data taken November 13 appear in Table I.

The first buds appeared on this variety about September 10. The data show that low pinching after the date of flower bud appearance increased the percentage of blind growths on the plants. Many of these growths eventually produced flowers, but from a commercial point of view would be considered blind. When the terminal growth was removed by pinching high, the lateral growths, which had already formed flower buds, developed normally and flowered. After low, late pinching, leaf rosettes developed, stems did not elongate and flowering did not occur.

The inheritance of blindness:—The fact that though the Natick plants were all propagated from blind stock, those which were not pinched low, late in the season, bloomed normally, would appear to indicate that some blindness is not inherited.

Summary

Heavy fertilization with nitrogenous materials, close planting and late planting of hardened plants failed to produce blind growth in chrysanthemum in the experiments described.

Tarnished plant bug injury, and in some cases late propagation and low pinching, resulted in blind growth.

The Effects of Day Length and Light Intensity on Vegetative Growth and Flowering of the China Aster (*Callistephus chinensis*)

By Kenneth Post, *Cornell University, Ithaca, N. Y.*

THE normal blooming time of the China aster in northern United States is from July 15 until October 15, depending upon the variety. This is during the time of year when the days are becoming progressively shorter and according to Garner and Allard (1) the China aster should be classified as a short day plant. If the equatorial length of day of 12 hours, as suggested by Kellerman (3), is used as a standard, this plant could belong to the long or short day group since some varieties bloom when the light periods are more than 12 hours and others when the light periods are less than 12 hours. They might be classified in the indifferent group but for the fact that previous experimentation with additional length of day by the use of electric light by Laurie and Poesch (4) and Green, Withrow, and Richman (2) have shown that additional light during the winter months reduces the time necessary for flowering. As a result of experiments carried on by Laurie and Poesch, the aster variety Sunshine was classified by them as a long day plant. Yet this variety blooms after August 15 when the days in the northern hemisphere are rapidly becoming shorter. Their results are based only on the effects of additional light during short days.

Results

The effects of additional day length:—During the winter of 1932 studies were made of the varieties Branching Red, Ball's Late White, Royal Rose, and Queen of the Market Scarlet aster plants. The seeds were sown during the month of October and the plants were benched in December. One plot which received 4 hours of additional light per day, from a 75-watt Mazda frosted glass lamp, hung 3 feet above the plants, showed a marked increase in vegetative growth over those plants receiving normal day length. The late varieties which were not given additional light formed a small rosette of leaves at the surface of the soil. They remained in this condition until May 10 when further vegetative growth occurred. The Royal and Queen of the Market varieties, which were not given additional light, bloomed a month before those given additional light, but the stems were short and the flowers small.

October 16, 1933, seeds were sown of the varieties Upright Branching White, Sempels, Shell Pink, Royal azure blue, and Queen of the Market dark blue. The seedlings were transplanted to 2-inch pots November 6 and transferred to the greenhouse bench December 5. The planting distance was 9 x 12 inches and the temperature of the greenhouse was kept at 50 degrees F at night. The day length was extended as previously outlined. Twelve plants of each variety were used in each treatment. The treatments and results appear in Table I.

It is evident from Table I that 12 hours of additional light per day did not prevent flowering. Nine and twelve hour treatments reduced

TABLE I—EFFECTS OF LENGTH OF DAY AND AGE OF PLANTS WHEN THE DAY LENGTH WAS INCREASED

Hrs. Light in Addition to Normal	Period of additional Light	Median Date Terminal Bloom		Blooming Period (Days)		Average Blooms per Plant		Average Stem Length (Inches)	
		Shell Pink	Market	Shell Pink	Market	Shell Pink	Market	Shell Pink	Market
0.........	Normal	*—	—	—	—	—	—	—	—
6.........	Nov. 6 to Dec. 4	—	2/22	—	28	—	1.8	—	1.2
6.........	Nov. 6 to Dec. 30	4/23	3/1	22	21	2.2	1.9	9.4	1.9
6.........	Nov. 6 to bloom	4/23	3/1	37	38	9.6	2.2	18.6	9.4
3.........	Dec. 5 to bloom	—	4/22	—	30	—	8.2	—	13.3
6.........	Dec. 5 to bloom	5/8	4/4	17	28	3.2	5.9	15.9	10.7
9.........	Dec. 5 to bloom	5/2	3/22	27	33	5.1	6.0	21.1	10.6
12.........	Dec. 5 to bloom	4/23	3/22	28	33	4.3	4.8	22.3	13.1

*No flowers

the time for flower production but extended the blooming period and stem length in comparison with a 6-hour treatment. The plants produced weaker stems when treated for the longer time. Stem elongation of all varieties occurred when 3 hours of additional light per day was given but late varieties did not flower with this treatment. Plants of all varieties given no additional light formed a rosette of leaves at the surface of the soil and remained in this condition until May 10 when the normal length of day reached about 14 hours. At that time the stems elongated and after a period of elongation flowers developed. None of the plants given normal day lengths flowered before June 20.

Plants which were given additional light while in 2-inch pots, from November 7 to December 5, bloomed earlier than those not treated during that time. With a treatment of 6 hours additional light per day Queen of the Market and Shell Pink were in bloom 34 and 15 days, respectively, in advance of those not treated. Treatment in 2-inch pots followed by normal day length forced early varieties to bloom in advance of those treated for a longer time. Late varieties produced rosettes of leaves and reacted similarly to those not treated. A light treatment of 6 hours per day for 2 months followed by normal day length forced all varieties to bloom at the same time as those treated continuously. The plants were dwarf, and produced shorter stems and smaller flowers than those treated for a longer time.

The effects of artificially reducing the length of day:—To determine the effects of artificially reducing the length of day, during the long days of summer, on the time of bloom, length of stem and flower diameter of China asters, seeds of Ball's Late White, American Branching Phlox Pink, Sempel's Shell Pink and American Branching purple were sown Feb. 28, 1933. The plants were transplanted from 3-inch pots to the field, under cloth protection (5), during the last week of May. Twenty plants were used to each treatment. One plot was given 10-hour days by covering the plants with black sateen cloth at 5 p.m. and removing it at 7 a.m. The treatment was started June 20 and continued until the flowers were cut. The data appear in Table II.

The plants which were given short days bloomed earlier than the checks and the blooming period was considerably shortened by the treatment. The stem length and flower diameter was likewise reduced.

TABLE II—THE EFFECTS OF ARTIFICIAL SHORT DAYS ON ASTERS

Variety	Treatment	Date First Bloom Cut	Days in Bloom Before Check	Cutting Period (Days)	Average Stem Length (Ins.)	Average Flower Diameter (Ins.)
Sempel's Shell Pink	Darkened	July 22	22	10	10.7	3.0
	Check	August 13	—	28	23.8	4.0
American Branching Purple	Darkened	July 26	20	14	11.4	3.2
	Check	August 15	—	28	21.3	3.8
American Branching Phlox Pink	Darkened	August 1	17	10	12.3	3.6
	Check	August 18	—	21	24.2	4.5
Ball's Late White	Darkened	August 1	17	10	14.3	3.2
	Check	August 18	—	28	27.6	3.5

Further and more extensive experiments were made during the year of 1934. The varieties Queen of the Market flesh pink, Early Royal rose, American Branching pearly pink and American Branching white were used in the experiments. One lot of seeds was sown March

TABLE III—EFFECTS OF TIME OF BEGINNING, DURATION OF SHORT-DAY PERIODS, AND THE DATE OF PROPAGATION ON THE TIME OF BLOOM AND QUALITY

	Variety American Branching White						
Treatment	Color Showing (Date)	First Flowers Cut (Date)	In Bloom Before Check (Days)	Cutting Period (Days)	Average Stems per Plant (No.)	Average Stem Length (Ins.)	Average Flower Diameter (Ins.)
Propagated March 1, given additional light, March 19 to May 15							
Darkened June 20 to bloom	7/2	7/7	61	13	6.6	21.6	3.1
Darkened July 1 to bloom	6/29	7/6	62	22	7.7	24.5	3.1
Not darkened	7/2	7/10	58	32	6.2	27.3	3.3
Propagated March 1							
Darkened June 20 to bloom	7/1	7/23	44	7	9.0	18.1	2.4
Darkened July 1 to bloom	7/25	7/30	38	7	8.9	22.1	2.5
Not darkened	8/7	8/11	26	31	7.3	30.8	2.9
Propagated April 15							
Darkened June 20 to bloom	7/27	8/1	36	10	12.5	12.9	2.6
July 1 to bloom	8/2	8/6	31	7	7.8	11.7	2.4
July 1 to 30	8/1	8/6	31	20	9.7	12.4	2.6
July 1 to 25	8/1	8/6	31	31	9.3	17.2	2.9
July 1 to 20	8/5	8/11	26	30	10.8	19.6	2.7
July 1 to 15	8/5	8/13	26	15	8.6	17.6	2.7
July 1 to 10	8/8	8/13	24	28	11.7	23.9	2.8
July 1 to 5	8/13	8/21	16	20	10.6	26.9	2.6
Not darkened	8/23	9/6	0	4	4.1	29.9	3.1

1 and a second lot April 15. Some of the plants, from seeds sown March 1, were given 4 hours additional light per day, as previously outlined, from the date they were transferred from the seed pan to 2-inch pots (March 19) until May 15. Some plants of the same sowing were given normal day length throughout this period. Plants from the April 15 sowing were given normal day length during this period. The specific treatments and results of American Branching white appear in Table III. All plants were grown during the summer under cloth protection. Where the plants were given short days, that is, darkened, the treatment was as outlined above. Plants propagated March 1 were planted from 3-inch pots May 15. Those propagated April 15 were planted in the field June 15.

Additional length of day in the early period of growth reduced the time for flowering of Queen of the Market 37 days, Royal Rose 26 days, and American Branching white 32 days when compared with plants propagated at the same time and given the same conditions other than day length. Queen of the Market plants given additional light in the early growing period bloomed immediately after they were planted in the field.

The time necessary for flowering for American Branching and Royals was reduced by 3 and 5 days, respectively, when the plants which had been given additional light were given short days starting June 20. When the treatment was started July 1 the date of flowering was advanced 4 and 9 days, respectively.

Queen of the Market, Royal, and Branching plants propagated March 1 and given normal day length previous to June 20 flowered 3, 13, and 18 days earlier, respectively. Similar plants, given short days starting July 1 produced flowers 1, 13, and 12 days, respectively, in advance of the normal treatment.

The cutting period was over a longer time for light treated plants than for those given normal conditions. Reducing the length of day reduced the length of the cutting period. Earlier short day treatments reduced the cutting period more than later treatments.

Additional day length early in the growing period reduced slightly the length of stem and production of the plants but it increased the size of the flower. Reducing the length of day reduced the length of stem and size of flower.

Early planting increased the number of stems per plant and stem length, but smaller flowers were produced. A comparison of the time of bloom of plants propagated March 1 and April 15 shows an advance of 10, 14, and 26 days for the Queen of the Market, Royal, and Branching types, respectively. The blooming period of early propagated plants was over a longer time than that of late propagated ones.

Five short days early in the growing period affected the time of bloom of all varieties treated. The effectiveness of the treatment in reducing the time necessary for flowering was in a direct relationship to the length of the treatment. Five short days in the early period of growth of Queen of the Market was ample to produce flowers. The stem length and flower diameter tended toward an inverse relationship to the effectiveness of the treatment.

Summary

1. Plants of early midseason and late varieties of China asters were grown in the greenhouse during the winter months and given various day lengths by the aid of electric lights during different periods of the life cycle of the plant. Plants of like types were grown during the summer months under cloth in the field and the length of day varied at different periods of the growth of the plants.

2. It was impossible to prevent the flowering of asters by the use of electric lights even though day lengths of 20 hours of light were given. It is possible that the intensity of the light was too low to accomplish this.

3. During a day length of less than 14 hours, aster seedlings produced a rosette of leaves, and when the length of day became greater than 14 hours, stem elongation occurred.

4. A period for stem elongation was necessary before flowering occurred and the period of elongation necessary was longer for late than for early varieties.

5. Flowers developed under day length periods greater and less than 14 hours but the most rapid development of flower buds, which had differentiated earlier, occurred during the shorter days.

6. All varieties of asters which were used responded to varying day lengths as typical short day plants even though they flowered under any length of day given.

7. Additional day length in the early period of growth reduced the time necessary for flowering of all varieties.

8. Additional day length in the early period of growth followed by reduced day length in summer after buds had developed produced flowers of normal size, on late types, earlier than other treatments.

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Temperature as a Factor in Bud Differentiation and Flowering of Stocks (*Mathiola incana*)

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

ANNUAL stocks frequently react as biennials in some sections of the United States. This reaction occurs more often in some localities than others and it is more general certain years. Along the Pacific coast and in the Adirondack Mountain area of New York state they are annuals and seldom react as biennials. When the seeds are planted early and the seedlings transferred to the field early in spring they have been observed to flower more frequently than those planted late. During the winter months in the greenhouse they seldom fail to flower when grown at a temperature between 45 and 60 degrees F.

The experiments reported in this paper were conducted to determine effects of temperature on bud differentiation and flowering of stocks.

In June, 1932, seeds of the variety Bismark Rose stocks were sown. The seedlings were transferred to 2-inch pots and later transferred to flats of soil, 12 x 15 x 4 inches. Fifteen seedlings were grown in each of five flats in the greenhouse. November 1 no flower buds had developed on any of the plants. At this time they were discarded because they had developed a large mass of foliage and a tremendous height.

January 23, 1934, seeds of Bismark lavender stocks were sown. The seedlings were transferred to pots and from there to flats as previously outlined. Some were kept at a temperature which never fell below 55 degrees F, but which frequently went as low as 55 degrees at night. Some were kept at a temperature approximately ten degrees lower. Those kept at the lower temperature all flowered while 18 plants of the 120 failed to flower at the higher temperature.

August 1, 1934, Column lilac lavender stock seeds were planted in the greenhouse where the temperature did not fall below 60 degrees F. They were transferred to 2-inch pots and to flats as previously outlined September 10. Four flats were kept at a temperature which never fell below 60 degrees F and four flats where the temperature never went below 50 degrees but as often as possible was lowered to 50 degrees. November 23, all plants kept at the lower temperature were showing buds while no plant at the higher temperature had budded. By December 20 all plants kept at the lower temperature had flowered while no buds were visible on those in the higher temperature.

SUMMARY

Stocks were grown at varying temperatures in the greenhouse. Under the conditions of the experiment no plants differentiated flower buds when the temperature was maintained above 60 degrees F. This failure to form buds is frequently known as blindness and is associated with the bienniel reaction of stocks grown under conditions of high temperature.

Controlling the Color of Greenhouse Hydrangeas (*Hydrangea macrophylla*) by Soil Treatments with Aluminum Sulphate and Other Materials

By R. C. Allen, *Cornell University, Ithaca, N. Y.*

ALUMINUM was found by Allen (1) to be responsible for the development of blue color in hydrangeas. The investigation reported in this paper was undertaken to determine the most efficient method of maintaining aluminum in an available form in the soil and to determine the effects of various materials upon the pH of the soil and upon the growth of the plants.

All plants used in these tests were of the variety Niedersachsen. They were propagated March 15 and unless otherwise stated were grown in pots using a composted potting soil of medium texture to which one-fourth by volume of peat moss was added. The initial pH of the soil mixture after at the time the experiments were started was 6.8. Tap water with a pH of 7.6 was used during the experiment and the pH of the soil gradually increased. The plants were grown in the greenhouse during the summer and October 1 were placed in a coldframe. December 1 they were placed in a greenhouse which was held at 45 degrees F. January 23 the temperature was raised to 55 degrees night temperature and the plants started to grow. The pH measurements were made by the quinhydrone electrode method.

Results

The effect of materials added to the potting soil:—A number of attempts were made to control the color of hydrangeas by mixing various substance with the potting soil. The results were always erratic and unsatisfactory and it seemed impossible to make any definite recommendations. Aluminum sulphate gave the best results of any of the materials used but this was not satisfactory because it was difficult to determine just how much should be applied to a given soil to lower the pH sufficiently to permit the aluminum to remain in a soluble condition.

Powdered sulphur was found to be very effective in lowering the pH of the soil but the pH could not be controlled when it was used. If it was used in sufficient quantity to lower the pH rapidly, the ultimate pH of the soil sometimes became so low as to injure the plants. When the pH was lowered to 3.5 by the use of sulphur the plants produced pink flowers instead of blue. The reason for this has not yet been demonstrated, but it is quite likely that at this low pH the aluminum was leached from the soil and the concentration became less than that necessary to produce blue flowers. When small quantities of sulphur were used and the pH did not go below 5, the resulting flowers were pink. This was probably because the change in hydrogen ion concentration took place so slowly that the plants flowered before enough aluminum was made soluble to produce blue flowers.

Other substances such as peat moss, ferrous sulphate, copper sulphate, magnesium sulphate, and manganous sulphate were used. All have certain disadvantages which limit their use for this purpose.

TABLE II—THE EFFECT OF APPLICATIONS OF 2½ PER CENT ALUMINUM SULPHATE SOLUTION UPON THE pH OF SOIL AND THE RESULTING FLOWER COLOR

Number of Application	Week													Color of Flower
	0	1	2	3	4	5	6	7	8	9	10	11	12	
0 (control)	6.8	6.8	5.4	6.6	6.5	6.4	6.4	6.6	6.9	6.8	6.8	6.8	6.9	Clear pink
1	6.8	5.5	5.4	5.5	5.7	5.6	5.6	5.9	6.1	6.4	6.6	6.8	6.8	Pink tinged blue
2	6.6	5.6	4.5	4.6	4.9	4.9	4.9	4.9	5.3	6	6.2	6.4	6.6	Nearly clear blue
5	6.6	5.0	4.8	4.4	4.1	4.0	4.1	4.2	4.4	4.4	5.7	6.2	6.2	Clear blue
10	5.7	5.6	4.8	4.5	4.0	3.8	4.0	4.1	3.8	4.1	4.0	4.1	4.5	Clear blue plants injured
12	6.7	5.3	5.1	4.2	3.9	3.8	3.8	4.0	3.8	4	4.2	4.1	4.0	Clear blue plants badly injured

The effect of materials applied in solution during the forcing period: —To determine the effect of various chemicals when applied to the soil in solution, a group of plants was selected and about 250 cc of the different solutions were applied to each plant at weekly intervals during the forcing period which was from February 1 to April 16. The plants were in 6-inch pots. The soil in which these plants were grown was not the same compost used in the other experiments but was the natural field soil classified as Dunkirk clay loam. The average pH of the soil at the beginning of the experiment of all the plants used was pH 7.5.

Table I shows the different materials that were used, the concentration, the effect upon the pH of the soil and the color of the flowers produced.

TABLE I—THE EFFECT OF VARIOUS SOLUTIONS UPON THE pH OF THE SOIL, AND THE RESULTANT FLOWER COLOR

Solution	pH After Three Applications	pH After Six Applications	pH After Nine Applications	Color of Flowers
Control, tap water.........	7.8	7.9	7.9	Pink
Aluminum sulphate, 2.5 per cent..................	6.5	4.7	4.2	Blue
Potassium alum, 2.5 per cent	6.5	5.6	4.7	Pinkish blue
Ferrous sulphate, 1 per cent.	7.3	6.3	5.2	Bluish pink
Copper sulphate, 1 per cent..	7.1	5.9	5.3	Bluish pink plants injured
Sulphuric acid, .1 per cent...	7.1	5.8	4.8	Pinkish blue
Citric acid, 1 per cent......	7.6	7.3	7.0	Pink
Hydrochloric acid, .1 per cent...................	7.5	6.8	6.3	Pink
Acetic acid, 1 per cent.....	7.7	7.4	6.7	Pink

As can be seen from Table I the only solution which satisfactorily produced blue flowers was aluminum sulphate. It is possible that potassium alum and sulphuric acid used in a little higher concentration would prove satisfactory and these are being tested further.

The number of applications of 2½ per cent aluminum sulphate solution applied during the forcing period necessary to produce blue flowers:—An attempt was made to determine the number of applications of a 2½ per cent solution of aluminum sulphate necessary, during the forcing period, to produce clear blue flowers. Ten plants in 5-inch pots were selected for each treatment. Two hundred cc of solution was applied to each pot at each application. Applications were made 1 week apart beginning January 30 and ending April 28 at which time all the plants had flowered.

Table II gives the number of applications used in each treatment, the average weekly pH readings and the color of the flowers produced.

The results which appear in Table II indicate that 5 applications of a 2½ per cent solution of aluminum sulphate were sufficient to produce blue flowers. Plants given ten applications were small and produced small flowers. They exhibited a tendency to wilt and inspection of the root system showed considerable root injury. Plants treated with 12 applications were injured to a greater extent and in some cases the edges of the leaves died and many of the lower leaves abscissed.

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The Effect of Soil Temperature on the Growth and Flowering of Certain Greenhouse Crops

By R. C. Allen, *Cornell University, Ithaca, N. Y.*

SOIL temperature is known to have an effect upon the growth of certain plant organs and upon the rate of certain plant processes, but little data are available to show the effect of soil temperature upon the flowering of plants. In the culture of greenhouse crops, it has been suggested that better growth and earlier flowering may be obtained by placing heating pipes under benches or along the sides of ground beds. The experiments here reported were made to determine what effect differences in soil temperature might have upon the growth, quality, and time of bloom of certain floricultural crops.

Three plots were laid out in adjacent greenhouse benches and two were equipped with 150 feet of Rockbestos, lead-covered, heating cable and a Penn Electric thermostatic switch. The soil used was a medium grade of compost, and an application of superphosphate was made at the rate of 5 pounds per 100 square feet of bench space at the time the soil was put in the bench. No other fertilizers were used until near the close of the experiment when ammonium sulphate was applied to one-half of each plot to determine whether or not the control plot was suffering from nitrogen deficiency. The air temperature of the house was kept as near 50 degrees F as possible, but the records show that it averaged a little higher. The soil temperature of the control plot was approximately that of the air, namely, 52 degrees F. Although the fluctuations in the soil temperature took place more slowly and were usually not as extreme as those of the air, the final monthly average proved to be essentially the same.

The thermostat in the second plot was regulated to maintain a soil temperature of 60 degrees F, 2 inches below the surface. The third plot was regulated to maintain a temperature of 72 degrees F. Temperature readings of the air and all plots were made three times a day.

Results

Greenhouse Stocks (Matthiola incana):—Seventy-five Bismark and 65 Column type stocks from 2-inch pots were planted in each of the plots on November 10th. The average number of days to flowering and the average length of stem are recorded in Table I.

TABLE I—The Effect of Soil Temperature on the Time of Bloom and the Length of Stem in Stocks

Soil Temperature (Degrees F)	Column Type		Bismark Type	
	Average Number Days to Bloom	Average Length Stem (Ins)	Average Number Days to Bloom	Average Length Stem (Ins)
52	99	32.7	114	31.8
60	102	34.3	126	31.4
72	102	34.4	122	32.1

The data of Table I indicate that soil temperature has very little effect upon the date of bloom in the Column type of stocks although there seems to be a slight retarding effect of the higher temperatures. In the case of the Bismark strain, however, there is a difference in the time of bloom of a week or more. There seems to be no practical difference in the length of stem in either type, although higher soil temperatures do tend to favor a slightly longer stem, particularly with the Column type.

Calendulas (Calendula officinalis):—Thirty Calendula plants of the variety Ball's Lemon Queen from 2-inch pots were placed in each plot November 10. The plants began flowering February 23 and continued until April 4 when the experiment was discontinued. The number of flowers per plant, the average length of the stems and the average diameter of the flowers are recorded in Table II.

TABLE II—THE EFFECT OF SOIL TEMPERATURE ON THE NUMBER OF FLOWERS PER PLANT, THE STEM LENGTH, AND THE DIAMETER OF THE FLOWERS OF CALENDULAS

Soil Temperature (Degrees F)	Number Flowers per Plant	Average Length of Stem (Ins)	Average Diameter of Flowers (Ins)
52	3.3	12.1	3.4
60	6.2	15.3	3.2
72	6.1	14.8	3.1

The results indicate that the higher soil temperatures brought about an increase in the number of flowers per plant and in the length of stem. The average diameter of the flowers was slightly less at the higher temperatures.

Snapdragons:—Thirty-six snapdragon plants, variety Cheviot Maid Supreme from 2-inch pots, were placed in each plot. The plants began to flower March 6 and finished April 1. The average number of days to bloom, the average length of the stems, and the length of the flower clusters are recorded in Table III.

TABLE III—THE EFFECT OF SOIL TEMPERATURE ON THE NUMBER OF BLOOMS PER PLANT, THE NUMBER OF DAYS TO BLOOM, LENGTH OF STEM AND LENGTH OF FLOWER CLUSTER OF SNAPDRAGONS

Soil Temperature (Degrees F)	Number Flowers per Plant	Average No. Days to Bloom	Average Length of Stem (Ins)	Average Length of Flower Cluster (Ins)
52	4.0	128	43.0	7.8
60	4.5	135	42.6	7.2
72	4.8	139	41.3	6.3

In the case of snapdragons, the data show that with an increase in soil temperature there was an increase in the number of flowers per plant, the number of days required for the plants to come into bloom, and the stem length, but the length of the flower cluster decreased.

Freesias:—Seventy-two freesia corms of the variety Purity Improved were planted in each of the plots November 10. The average number of days to flowering, the number of flowering stems per corm, and the average stem length are recorded in Table IV.

TABLE IV—THE EFFECT OF SOIL TEMPERATURE UPON THE TIME OF BLOOM, NUMBER OF STEMS PER CORM, AND THE LENGTH OF STEM OF FREESIAS

Soil Temperature (Degrees F)	Number Flowers per Corm	Average Number Days to Flowering	Average Length Stem (Inches)
52	1.48	116	11.5
60	1.97	114	11.6
72	0.67	131	10.7

The data of Table IV indicate that increasing the soil temperature from 52 to 60 degrees F increased the number of flowers per corm and slightly shortened the time required for the corms to come into flower. The length of stem was practically the same. Increasing the soil temperature from 60 to 72 degrees F very markedly decreased the number of flowers per corm and greatly increased the time required for the plants to come into bloom.

DISCUSSION

From the appearance of plants growing in the different plots, it seemed evident that not all of the differences in growth noted could be attributed directly to soil temperature differences. The calendula and snapdragons in particular, which were growing in the 52 degree F plot, showed marked symptoms of nitrogen deficiency. Ammonium sulphate solution (1 ounce to 1 gallon of water) was applied to one half of each plot. The plants so treated in the 52 degree F plot soon recovered. A slight improvement was noted in the 60 degree F plot, but no change was observed in the 72 degree F plot. It appears then, that at least part of the effect of high temperature in the greenhouse bench is to hasten the process of nitrification in the soil.

The Effect of Storage Temperatures on Flowering of Greenhouse Hydrangeas (*Hydrangea macrophylla*)

By R. C. Allen, *Cornell University, Ithaca, N. Y.*

OBSERVATIONS suggested that the method of storing greenhouse hydrangea plants prior to forcing made considerable difference in the time required for the plants to come into bloom. An experiment was set up to compare the effects of storage in a coldframe, a 33 degree F refrigerator and a 50 degree F greenhouse. Greenhouse grown plants of the variety Niedersachsen were used for the tests. On October 15, a group of plants was placed outside in a coldframe where the plants were covered with coldframe sash at night. On the same date another group was placed in a 33 degree F refrigerator. A third group was placed directly on a greenhouse bench in a house where the temperature was kept constantly as near 50 degrees F as possible. At 2-week intervals, 10 plants were removed from both the coldframe and the 33 degree F refrigerator and placed in the 50 degree F house. The plants were considered in bloom when color first showed. Table I gives the average number of days for the plants to come into bloom after termination of the treatment and removal to a 50 degree F house.

TABLE I—The Average Number of Days Required for Hydrangeas to Come into Bloom at 50 Degrees F After Storage for Various Lengths of Time Under Different Conditions

Number of Weeks in Storage	Coldframe	33-Degree F Refrigerator	50-Degree Greenhouse
0	—	—	187
2	167	161	—
4	154	128	—
6	127	113	—
8	113	105	—
10	102	95	—
12	88	91	—

The results show that the storage conditions affect the time required for the plants to come into bloom. Storing the plants in a 50 degree F house greatly lengthened the time. Storage for 4 to 6 weeks at 33 degrees F followed by growth at 50 degrees F gave most rapid blooming.

These tests are being extended to include other varieties and different storage conditions.

The Value of Peat in a Potting Soil Mixture[1]

By L. E. LONGLEY, *University of Minnesota, St. Paul, Minn.*

PEAT has recently been employed in large quantities as one of the ingredients of the potting soil mixture for greenhouse plants, largely as a replacement for leaf mould, etc. Its value has most often been considered to be due to the fact that it puts the soil in a better physical condition for root growth.

Peat contains considerable nitrogen, often as high as 4 per cent in some sedge peats, but until recently it has been thought that this nitrogen becomes available only very slowly. Laurie (1), however, has reported considerable increased vegetative growth where peat has been used in the soil mixture, when it was combined with a small amount of manure. He attributed this to the fact that the manure furnished inoculation of bacteria which rendered much of the nitrogen available. McCool (2, 3) demonstrated that manure or certain fertilizers combined with peat for some months will bring about the changing to the nitrate form of several times as much nitrogen as will be changed in the peat not so composted. He also demonstrated increased growth in certain crops grown in pots of soil to which a portion of the various composted peats had been added. He found some difference in nitrate formations when different types of peat were employed, but these differences were not so great as had been commonly supposed.

Materials and Methods

The experiments outlined in this paper were begun in 1930, as an attempt to see how far peat may be substituted for manure in the potting soil mixture in the case of a few common greenhouse plants of several types.

In the first series, three different types of peat were employed, namely, No. 1, Nutria peat, a grass sedge peat, basic in reaction and very well decomposed; No. 2, Corona acid peat; and No. 3, Corona basic peat. Nos. 2 and 3 are peats formed partially of sphagnum and are less decomposed than the Nutria peat.

Results

Table I gives the yield of certain plants grown in combinations of these peats with varying quantities of manure. It will be noted that the soil in Plot 13 is a common potting soil formula and in Plots 1–9 various proportions of peat are substituted for all or part of the manure. The soil used in Plots 10–12 is pure peat of the various types. The plants employed were *Vinca major variegata*, *Iresine lindeni*, *Coleus blumei*, Annual larkspur, and Calendula. These produced from cuttings were rooted and potted first into 2½-inch pots and then later into 6-inch pots, using the soil mixture for the respective plots in both sets of pots and those from seed grown on in a similar manner. From 10 to 15 pots were included in each lot. The plants were grown to a fair size, then they were cut at the surface of the ground and weighed.

With Vinca the growth was rather erratic but the indications were that the mixture with much or even all of the manure replaced with

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peat gave as good result as the basic mixture with manure and no peat. With Iresine the mixture with ¾ of the manure replaced by peat gave the best results with all types of peat. The regular potting mixture with no peat ranks sixth. Here the indications are that a high percentage of the manure may be replaced by peat with benefit. With Coleus the mixture with manure and no peat gave best results. Those having ½ of the manure replaced with peat ranked next though considerably poorer.

Notes taken on the blooming of annual larkspur included in the experiment indicate that Plots 7, 8, and 9 (these lots have ½ the manure replaced by peat) came into bloom earliest and gave better flowers. No. 13, the basic soil mixture, gave as good blooms as these plots but was several days later in blooming. Nos. 4, 5, and 6 were both later and poorer, and Nos. 1, 2, and 3 were very weak in growth, while those in the pure peat mixtures nearly all died without blooming. In general, the indications for Larkspur are that considerable peat in the mixture may replace manure with benefit, especially in earliness of blooming, but this plant does not thrive when no manure is present in the mixture. With Calendula, Plot 6, (Corona basic peat ¾ part, manure ¼ part) produced the most flowers per plant followed by Plot 13, (the basic soil mixture) and Plot 7 (Nutria peat ½ part, manure ½ part). In flower diameter the ranking is as follows: Plots 7, 8, and 9, with 4, 5, and 13 very close. In stem length, Plot 10 ranked highest but the stems were slender and the flowers small. Plot 13 ranked next, with all the others somewhat shorter, and not greatly different from each other. All this would indicate that the mixtures in which peat was substituted for part of the manure were as good or even better than the soil-manure-sand mixture.

In the second series, fewer plots were used. Table II gives the yield of various plants in this test. With Begonia, the basic potting mixture (No. 1) was best, giving a more stocky, compact growth, but all the mixtures gave fairly good results. This was true even of the mixture having all the manure replaced by peat; even the pure Nutria peat grew a fairly good begonia plant as far as weight was concerned, though the stems were weaker and inclined to droop, probably because of lack of potassium. Nos. 2 and 3 gave more rank, succulent growth than No. 1, being inclined to throw up some tall coarse stems. This evidently shows the presence of abundant nitrogen. The results with *Abutilon savitzi* were somewhat similar, though here the lot with ¾ of the manure replaced by peat was a trifle better than the others. Nos. 1 and 2 showed many rank succulent stems, showing the presence of available nitrogen. *Linaria maroccana* was included in this series. No. 3 mixture (½ part manure and ½ part peat) gave the heaviest growth with most flowers with No. 2 (¼ part manure, ¾ part peat) somewhat weaker in growth and less floriferous. No. 1 was still poorer; No. 4 was about the same as No. 2, but Nos. 5 and 6 were irregular in growth but about as good as No. 1.

In Calendula, Plot 4 (soil, Nutria peat, sand) had the most flowers, followed closely by Nos. 3, 2, and 1. No. 1 produced the longest stems with No. 4 next, and the others a trifle shorter. No. 3 produced

TABLE I—YIELD OF PLANTS IN POTS GROWN IN SOILS HAVING VARYING PROPORTIONS OF PEAT—SERIES 1

Plot	Composition of Soil	Ave. Green Weight (Grams of Plants)			Yield of Flowers of Calendula (17 Pots per Plot)		
		Vinca major	*Iresine herbsti*	*Coleus blumei*	No. Flowers per Plot	Average Diameter (Ins)	Average Length of Stem (Ins)
1	Soil 3 parts, Nutria peat 1 part, sand 1 part	5.0	6.2	28.5	57	2.5	11.0
2	Soil 3 parts, Corona acid peat 1 part, sand 1 part	4.7	8.4	27.5	58	2.6	11.2
3	Soil 3 parts, Corona basic peat 1 part, sand 1 part	4.4	5.0	24.5	78	2.6	11.0
4	Soil 3 parts, Nutria peat ¾ part, manure ¼ part, sand 1 part	4.1	11.0	48.5	84	2.7	11.4
5	Soil 3 parts, Corona acid peat ¾ part, manure ¼ part, sand 1 part	3.9	9.2	52.0	86	2.7	10.3
6	Soil 3 parts, Corona basic peat ¾ part, manure ¼ part, sand 1 part	3.6	9.5	47.0	102	2.5	10.5
7	Soil 3 parts, Nutria peat ½ part, manure ½ part, sand 1 part	3.4	5.0	64.0	92	2.8	11.1
8	Soil 3 parts, Corona acid peat ½ part, manure ½ part, sand 1 part	3.4	6.25	72.5	83	2.8	10.9
9	Soil 3 parts, Corona basic peat ½ part, manure ½ part, sand 1 part	3.3	9.0	69.5	77	2.8	10.9
10	Pure Nutria peat	3.3	6.0	26.0	64	2.3	14.0
11	Pure Corona acid peat	1.6	3.4	19.5	0	—	—
12	Pure Corona basic peat	1.3	2.4	10.0	0	—	—
13	Soil 3 parts, manure 1 part, sand 1 part	0.9	6.25	94.0	94	2.7	12.9

TABLE II—YIELD OF PLANTS IN POTS GROWN IN SOILS HAVING VARYING PROPORTIONS OF PEAT—SERIES 2

Plot	Composition of Soil	Average Green Weight (Gms of Plants)			Yield of Flowers of Calendula (20 Pots per Plot)		
		Iresine herbsti	*Abutilon savitzii*	*Begonia argenteo guttata*	No. Flowers per Plot	Average Diameter of Flowers (Ins)	Average Length Stem (Ins)
1	Soil 3 parts, manure 1 part, sand 1 part	92.2	36.5	266.0	149	2.8	9.4
2	Soil 3 parts, Nutria peat ¾ part, manure ¼ part, sand 1 part	100.0	37.5	227.5	151	2.8	8.0
3	Soil 3 parts, Nutria peat ½ part, manure ½ part, sand 1 part	114.2	35.0	222.0	153	3.1	8.3
4	Soil 3 parts, Nutria peat 1 part, sand 1 part	77.2	32.5	236.0	164	2.9	8.8
5	Pure Nutria peat	86.9	32.1	218.0	131	2.9	8.0
6	Pure Corona acid peat	76.9	16.9	16.0	89	2.7	7.8

the largest flowers followed by Nos. 4 and 5 (pure Nutria peat). This would indicate still further that Calendula grows better in a mixture with part of the manure at least replaced by peat. In fact, a fair number of flowers of average size were produced in pure nutria peat, though the corona peat which is acid did not give good results.

Plants of French marigold showed best growth and blooming in No. 1 with No. 3 considerably poorer, and Nos. 2, 4, and 5 still poorer and smaller; No. 6 very poor and small. Browallia gave the best growth and most bloom in Plot 1 with Nos. 2 and 3 considerably poorer; Nos. 4 and 5 show a very depressed growth, indicating lack of nitrogen. Schizanthus gave earlier blooming in Plot 1 with No. 2 somewhat later but with more vegetative growth; and No. 3 was still later and No. 4 very late. Nos. 5 and 6 were very poor and weak.

For this second series the following seems true. The basic soil mixture, with no replacement of the manure with peat, seems best with French marigold, Browallia and Schizanthus. With the other plants replacement of ½ or ¾ of the manure by peat gave beneficial results.

In the third series, an attempt was made to ascertain whether there was any difference in increased growth if small quantities of manure, and also certain fertilizer chemicals, were composted with the peat some months before it was used in the potting soil mixture. The chemicals used were sulphate of ammonia or nitrate of soda combined with ground limestone and superphosphate. These mixtures are similar to some that have been used to hasten decomposition of straw or other organic matter in making so-called artificial manure. The plants in the plots containing these chemicals had a depressed growth at first but in most cases they later became more or less normal in growth.

Table III gives the results obtained with Iresine, Coleus, and Calendula in this series. With Iresine the regular soil mixture No. 12 is poorest though there is no regularity in any of the results. The mixture with peat combined with ammonium sulfate (Plots 4 and 9) ranks well up among the better plots. The lots in which the manure had been composted with the peat were poorer than the freshly made up mixtures. It should be noted that the lots having the chemicals added (Plots 4, 5, 9, and 10) give brighter colored foliage than did the other mixtures. With Coleus also the mixtures containing manure and peat are better than the basic potting soil No. 12. There seemed to be little difference whether there is much or little manure combined with the peat, except the half and half mixture is poorer than the smaller amounts. The lots with chemicals are better than No. 12, but not so good as the manure-peat combinations.

With Calendula the results are as follows: In number of flowers No. 9 was the best with Nos. 5, 10, 3, 6, 11, and 12 close together but somewhat less than No. 9, the poorest being Nos. 7, 4, and 1. In flower diameter there were no striking differences, but Nos. 4 and 5 were slightly the largest and No. 12 the smallest. In flower stem length, Nos. 1 and 2 were best with Nos. 10 and 12 not much

TABLE III—YIELD OF PLANTS IN POTS GROWN IN SOILS HAVING VARYING PROPORTIONS OF PEAT—SERIES 3

Plot	Composition of Soil	Av. Green Weight (Gms of Plants)		Yield of Flowers of Calendula (13 Pots per Plot)		
		Iresine herbsti	*Coleus blumei*	No. Flowers per Plot	Average Diameter (Ins)	Average Length Stem (Ins)
1	Soil 4 parts, Nutria peat 4/5 part, manure 1/5 part*, sand 1 part	31.0	46.7	47	3.2	9.5
2	Soil 4 parts, Nutria peat 8/9 part, manure 1/9 part*, sand 1 part	41.5	50.2	57	3.3	9.7
3	Soil 4 parts, Nutria peat 16/17 part, manure 1/17 part,* sand 1 part*	39.0	45.3	64	3.4	8.4
4	Soil 4 parts, Nutria peat 1 part, mixture A 1 part*, sand 1 part	42.0	40.3	56	3.6	8.8
5	Soil 4 parts, Nutria peat 1 part, mixture B 1 part*, sand 1 part	34.5	34.0	69	3.6	7.9
6	Soil 4 parts, Nutria peat 4/5 part, manure 1/5 part†, sand 1 part	41.5	42.7	64	3.2	7.3
7	Soil 4 parts, Nutria peat 8/9 part, manure 1/9 part†, sand 1 part	29.8	43.7	57	3.3	8.1
8	Soil 4 parts, Nutria peat 16/17 part, manure 1/17 part†, sand 1 part	41.6	42.6	60	3.4	8.7
9	Soil 4 parts, Nutria peat 1 part, mixture A 1 part†, sand 1 part	41.3	33.1	80	3.2	8.8
10	Soil 4 parts, Nutria peat 1 part, mixture B 1 part†, sand 1 part	35.8	20.7	68	3.3	9.1
11	Soil 4 parts, Nutria peat ½ part, manure ½ part†, sand 1 part	35.0	32.6	64	3.3	8.9
12	Soil 4 parts, manure 1 part†, sand 1 part	30.6	37.8	63	3.1	9.1

*Composted 1 year before using.
†Mixed together at time of making up the soil and not composted.
Mixture A. (Ground limestone 1.2 pounds, Sulfate of Ammonia 1.35 pounds, superphosphate .45 pounds. Amount mixed with 1 bushel of peat).
Mixture B. (Ground limestone 1.2 pounds, Nitrate of Soda 1.35 pounds, superphosphate .45 pounds. Amount mixed with 1 bushel of peat).

shorter. Nos. 3 and 12 were especially early in coming into bloom with Nos. 7, 5, 6, and 9 nearly as early but Nos. 1, 4, and 10 were delayed from a week to ten days. This indicates that substitution of a considerable amount of peat for the manure in a potting soil mixture can be made, and even better growth and number of flowers obtained. The addition of extra nitrogen particularly in the form of sulphate of ammonia also gives good results.

A series of Stocks was included. There was some difference in earliness of flower, Nos. 4 and 7 producing the majority of their bloom several days earlier than the others with Nos. 1, 3, 6, and 10 following these fairly closely, and Nos. 2 and 8 only a trifle later. Nos. 9, 11, and 12 were greatly delayed in blooming. This indicates the peat tended to promote earlier blooming whether with manure or with chemicals. The exception in the case of No. 9 was due to the fact that the chemicals mixed fresh with the soil greatly depressed the growth of the plants in their early stages.

In general, the results for the third series indicate that though there are somewhat different results, depending on the plant used, the following points are true in the case of the plants used in this series: (A) Rather large proportions of manure may be replaced by peat in a potting soil mixture; (B) the manure may be entirely replaced by the combinations containing ammonium sulphate or nitrate of soda combined with limestone and superphosphate, with nearly as good results as when some manure is used; (C) it seems to make little difference whether the manure or chemicals are composted for some time with the peat or whether they are mixed up fresh at the time of potting.

Summary

As good or better yields have been obtained when a considerable portion of the manure of a basic potting soil mixture has been replaced by peat when compared to the yields obtained from the basic potting mixture with most of the plants employed. This was true with Coleus, Iresine, Calendula, Vinca, *Begonia argenteo-guttata, Linaria maroccana,* and Annual Larkspur. French marigold, Browallia and Schizanthus, however, gave best results in the potting soil mixture with none of the manure replaced by peat. With *Begonia argenteo-guttata,* practically as good results were obtained when all the manure was replaced by peat.

Replacement of the manure by various materials commonly used in making artificial manure gave as good results as when manure was used with Calendula and Iresine, and nearly as good results with Coleus.

Composting the peat with manure or the chemicals for a year was no more effective than mixing it up fresh at the time of potting.

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The Forcing of Paper White Narcissus Bulbs After Storage at Various Temperatures

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In 1932 and 1933 several experiments were conducted with paper white Narcissus bulbs at the cold storage laboratory on the Arlington Experiment Farm, Rosslyn, Virginia. The bulbs were thoroughly mixed and all of the lots were selected at random. After storage for varying periods at different temperatures and humidities the bulbs were moderately forced in the greenhouse at a temperature of about 55 degrees F.

Since the actual value of a crop to the commercial grower is usually dependent on quality rather than on productiveness, more weight was given to the former in comparing the effects of different treatments. The percentage of spikes which had nine or more florets and the average number of florets per spike were used as fairly accurate criteria for measurements of quality. These are given in Table I together with the percentage of blooms that were produced. Foliage heights and floret diameters were recorded but are not presented here since even the smallest spikes that were measured were considered salable. After placing the bulbs on the greenhouse bench a number of days must elapse before a fair cut can be made. The length of this and the ensuing period during which the bulk of the crop can be cut are considered important to the commercial grower. In this paper where the time of blooming is discussed the number of days stated first is the time at which a fair cut was made but is not the date of the first bloom.

The number of days mentioned last is the termination of the peak of the crop or when the flats could have been placed in a less favorable position in the greenhouse.

1932 Experiment

The 1932 test was conducted on Texas-grown paper white Narcissus bulbs of the 13–14 cm size. When received on November 11 the bulbs when cut showed miniature spikes of ½ to 1 inch in length. Under what conditions this development occurred is not known.

Treatment:—The bulbs were received and stored the same day, being apportioned into the following groups: (A) Potted immediately and stored (six bulbs in a 7- or 8-inch pot); (B) held in baskets at low relative humidity (70 to 75 per cent); and (C) placed in baskets at high relative humidity (85 to 90 per cent). Each of these three groups was divided into lots of 12 bulbs each and stored at 40, 50, 60, 70, and 80 degrees F. Included also were two check lots, one potted and one loose in baskets that were stored in an ordinary bulb house at an average temperature of about 60 degrees with moderately high relative humidity. These were all removed from storage after 4½ weeks, when the low and high humidity groups were potted. All were then placed directly in the greenhouse.

TABLE I—CONDITIONS OBSERVED WITH PAPER WHITE NARCISSUS BULBS IN 1933 AFTER STORAGE AT 40, 50, 60, 70, AND 80 DEGREES F FOR 7, 12, AND 16 WEEKS WITH ACCOMPANYING GROUPS MOVED TO HIGHER AND LOWER TEMPERATURES FOR ABOUT 2 WEEKS

Initial Storage Temperature (Degrees F)	Storage Temperature to Which Moved for Approximately 2 Weeks (Degrees F)	Percentage of Spikes Cut and Time in Storage			Percentage of Spikes with Nine or More Florets and Time in Storage			Average Number of Florets and Time in Storage		
		7 Weeks	12 Weeks	16 Weeks	7 Weeks	12 Weeks	16 Weeks	7 Weeks	12 Weeks	16 Weeks
40	Continuous	94.0	18.2	0.0	16.1	0.0	—	7.1	4.3	—
40	60	63.5	15.2	0.0	4.8	0.0	—	5.3	3.2	—
40	70	100.0	6.0	0.0	8.8	0.0	—	7.3	4.0	—
40	80	88.0	3.0	0.0	37.9	0.0	—	7.6	8.0	—
50	Continuous	30.4	9.1	0.0	10.0	0.0	—	6.2	4.0	—
50	70	36.4	0.0	0.0	8.3	—	—	6.2	—	—
50	80	30.4	0.0	0.0	0.0	—	—	6.7	—	—
60	Continuous	72.7	63.6	35.5	8.3	4.8	0.0	6.1	5.6	5.1
60	80	69.7	24.2	3.2	8.7	0.0	0.0	6.6	5.0	6.0
70	Continuous	94.0	82.0	90.7	41.9	0.0	0.0	8.6	5.6	3.6
70	50	97.0	75.7	75.0	28.2	0.0	0.0	7.3	5.1	5.5
80	Continuous	100.0	97.0	96.8	60.5	84.5	76.7	9.4	10.1	9.6
80	60	94.0	85.0	91.0	61.2	32.2	43.4	8.8	8.3	7.9
80	50	97.0	91.0	93.7	53.1	26.7	56.7	8.4	6.9	9.2
80	40	91.0	100.0	96.8	76.7	57.1	86.2	9.6	8.6	9.8

RESULTS IN 1932

Percentage of blooms cut:—In almost all of these conditions the percentage of blooms cut was satisfactory and ranged from 91.5 to 100.0, the exceptions being the 60-degree F high humidity which gave 75.0 per cent bloom and the 70-degree low and the 70-degree high humidities with 58.3 and 66.6 per cent, respectively. The only temperature to give 100 per cent cuts in the potted, low humidity and high humidity groups was 80 degrees.

Percentage of flower spikes with nine or more florets:—A comparison of the potted bulb-house check lot with the bulb-house check held in baskets shows the latter to have produced 84.7 per cent of spikes with nine or more florets as against 81.9 per cent for the former. In the 40-degree F group the low humidity lot gave 91.7 per cent of such flower spikes with 66.6 and 82.0 per cent respectively, for the potted and high humidity lots; in 50 degrees the low humidity showed 77.0 per cent, whereas the potted lot and those from high humidity gave 71.3 and 72.7 per cent, respectively. In the 60-, 70-, and 80-degree groups there was not much variation in the percentage with 9 or more florets in the potted and high humidity lots which had a combined average for the six cases of 87 per cent; in the low humidity lot the average for these three temperatures was only 61.1 per cent.

Average number of florets:—The bulb-house dry check lot showed an average number of florets of 11.0 as against 10.3 for the potted check. In the 40-degree F group the average number of florets in the low humidity lot was 11.6 as compared with 9.1 in the potted and 11.0 in the high humidity lots. In the 50-degree group the average number of florets in the low humidity lot was 10.6, and in the potted and high humidity lots 8.6 and 10.2, respectively; those from the 60-degree storage showed a low humidity average of 9.7 florets, whereas in the potted and high humidity lots the averages were 11.4 and 11.5, respectively. The averages from the 70-degree group were 10.8 florets for the potted, 7.7 in the low humidity, and 13.0 in the high humidity lots. The low humidity lot from 80 degrees gave 9.2 florets as compared with 10.7 for the potted and 9.7 for the high humidity lot.

Time of blooming:—The potted lot under all conditions except at 40 and 80 degrees F gave a range of 35 to 42 days, within which the bulk of the crop was cut after the pots were placed in the greenhouse. At 40 degrees most of the flowers were cut between 35 and 46 days, and at 80 degrees the peak range was 42 to 52 days. The low and high humidity lots under all conditions had 42 days as the first date of the bulk of the cut, by which time most of the potted lots had been well cut over. The bulk of the crop had been cut after 46 days under most conditions except the 40, 50, and 80 degree F lots the cutting of which extended to 55 days.

1933 EXPERIMENT

In 1933, one experiment was made with Florida-grown bulbs ranging from 13 to 16 cms in size. These had been planted in the field on October 1, 1932, and the average temperature during the growing

season was about 65 degrees F. The flower spikes were not allowed to seed. After digging on May 1, 1933, the bulbs were stored on trays in large barns at De Land where the mean temperatures for May, June, and July were 79.0 degrees, 78.8 degrees, and 81.2 degrees F, respectively. The same data as described under the 1932 experiment were recorded for comparisons. In the discussion the initial storage temperature and the one to which the bulbs were subsequently moved will be stated in this order, as 40 degrees to 80 degrees F. In the accompanying table each of the main headings, 7, 12, and 16 weeks, include the entire storage period.

Treatment

This stock of paper white Narcissus was received at Arlington Farm, Rosslyn, Virginia, on August 14, 1933, and was divided into groups of 100 bulbs. Four groups were placed at 40 degrees F, 3 at 50 degrees, 2 at 60 degrees, 2 at 70 degrees, and 4 at 80 degrees. Each group consisted of a check (or continuous) lot that remained at the initial storage temperature and other lots that were moved periodically from the initial temperature after 5, 9, and 14 weeks to either higher or lower temperatures, where they remained for 16, 20, and 15 days, respectively, before planting. Each lot of 33 bulbs was then flatted and placed on the greenhouse bench.

Percentage of blooms cut:—The 40-degree F check group compared favorably with the lots moved from 40 degrees to 60, 70, and 80 degrees after 7 weeks but decreased in the 12-week storage with none cut after 16 weeks. The 40- to 60-degree lot did not give as many blooms as other lots in this group; the cuts from 40 to 70 degrees and 40 to 80 degrees were good for the 7-week storage only. None was cut after 16-week storage in any condition using 40 degrees as an initial storage temperature. The 50-degree check bulbs and those with 50 degrees as the initial temperature gave poor results from each planting, the highest cut being 36.4 per cent. The 60-degree check and the 60- to 80-degree lots gave about a 70 per cent cut after 7-week storage but on the whole no planting of these groups was satisfactory. The cuts of blooms from the 70-degree check and the 70- to 50-degree groups did not fall below 75 per cent throughout the test. The 80-degree check and all groups with 80 degrees as an initial temperature had good cuts for the duration of the test, the lowest quantity produced being 85 per cent.

Percentage of spikes with nine or more florets:—In all conditions for the three periodic plantings the percentages of spikes with nine or more florets were unsatisfactory except the 80-degree F check and moved lots which had 80 degrees as the initial temperature. Among these moved lots, the 80- to 60-degree group after 12-week storage gave 32.2 per cent and after 16-week storage gave 43.4 per cent of spikes with nine or more florets; the 80- to 50-degree group showed 26.7 per cent after 12-week storage. Other groups having 80 degrees as the original temperature gave percentages ranging from 53.1 to 86.2 of spikes with nine or more florets.

Average number of florets:—In general, all conditions were satisfactory as regards the average number of florets after 7-week storage,

the 80-degree F check and those with 80 degrees as the original temperature being slightly better as a rule than other lots. A marked decrease in the average number of florets between the 7 and 12 weeks' storage plantings was the general rule in all groups except the 40- to 80-degree, the 80-degree check, and groups with 80 degrees as the initial temperature. After 16-week storage the average number was not satisfactory in any but the 80-degree check, the 80- to 60-degree, the 80- to 50-degree, and the 80- to 40-degree lots.

Time of blooming:—The number of days between which the bulk of each crop was cut are given in the lots where quality was not sacrificed, namely, the 80-degree F check and the other groups having 80 degrees as the original temperature.

After 7-week storage the bulk of the crop was cut in the 80-degree F check lot between 80 and 84 days after planting, in the 80- to 40-degree lot between 76 and 88 days, in the 80- to 50-degree and 80- to 60-degree lots between 65 and 76 days.

After storage for 12 weeks the peak of the cut in the 80-degree F check lot lay between 74 and 80 days after planting, in the 80- to 40-degree lot between 69 and 80 days, in the 80- to 50-degree lot between 64 and 80 days, and in the 80- to 60-degree lot between 60 and 69 days.

In the 16-week storage group the bulk of the crop was cut in the 80-degree F check lot and the 80- to 40-degree lot between 65 and 70 days after planting, and in the 80- to 50-degree and the 80- to 60-degree lots between 56 and 65 days.

Summary

In the 1932 experiment the number of bulbs used in each lot (12) was too small to warrant any final conclusions. However, the results indicate that for 4½-week storage the total cut was satisfactory when the bulbs were stored potted and also when held in baskets at both high and low humidities. Considering the quality of the spikes it appears that at temperatures as low as 40 or 50 degrees F a low humidity was advantageous but that at 60 degrees or above, a high humidity when stored loose or the potting of the bulbs before storage was more desirable than storage at a low humidity. Potting the bulbs about 1 month previous to placing them in the greenhouse gave good quality blooms from all of the temperatures used. On an average these started with a fair cut about 10 days earlier and finished blooming about 5 days earlier than those stored loose in baskets at high and low humidities. It would appear that if the bulbs are potted as just described a temperature range of 60 to 70 degrees F would be more desirable than 80 degrees, which has a retarding effect, and would also be preferable to a lower temperature.

Judging from the 1933 experiment, bulbs stored continuously at 40 degrees F and moved lots having 40 degrees as the initial temperature gave good cuts but the quality was inferior. The 50-degree check group and those groups with an initial temperature of 50 degrees gave poor cuts of poor quality blooms which does not agree entirely with the results of the 1932 test. The 60- and 70-degree groups and other groups having these as original temperatures gave fair cuts in all

cases but the quality of blooms was not the best. The only conditions that gave satisfactory results throughout the test were the 80-degree check, 80- to 60-degree, 80- to 50-degree, and 80- to 40-degree groups, which gave good cuts of high quality blooms with only one instance out of 12 cases showing only a fair average number of florets.

There was some fluctuation in the number of spikes with nine or more florets in the 80-degree check and other groups with 80 degrees as the initial temperature. This was probably due to inherent floret differences within any one lot of 33 bulbs, but this is mostly overcome if the judging of quality is based on the average number of florets.

Since, according to the 1933 experiment, the 80-degree F check produced slightly better results throughout the test than any other group there is no reason to suggest the moving of paper white Narcissus bulbs stored at 80 degrees in August to a lower temperature for a short period unless it be to advance the blooming period somewhat, in which case quality at times might be sacrificed. The lowering of the temperature from 80 to 50 degrees or 60 degrees advanced the initial cutting date for the bulk of the crop from 5 to 15 days over the 80-degree check and 80- to 40-degree groups, and in most cases throughout the test these bulbs were off the bench from 5 to 12 days earlier than the 80-degree check and 80- to 40-degree groups. However, the bulk of the 80-degree check crops was cut within 4 to 6 days after blooming as compared with a range of 9 to 16 days in other groups involving 80 degrees as the initial temperature. These factors must be considered collectively but weighed individually according to the grower's needs.

Status of Orchard Soil Moisture Research (Presidential Address)

By J. R. Magness, *U. S. Department of Agriculture, Washington, D. C.*

THE late Charles Reid Barnes emphasized the importance of water to plant life by defining a plant as a supported column of water. By such a definition one recognizes that all physiological processes in plants occur in solutions and can not take place unless large quantities of water are present. Physiologists and horticulturists alike have long recognized the vital part that water supply plays in the functioning of plants.

Much of the research on moisture relations in plants has been based on annuals generally growing in pots, with only limited studies, at least until recent years, on fruit or forest trees. The reason for this rather limited amount of critical orchard research on soil moisture and its relation to fruit production is easily understood. Definite pre-determined control of moisture conditions in orchard plots can not be obtained, at least below the point of approximate soil saturation and above the wilting percentage. In the irrigated orchard districts of the West, control within certain limits is possible, but even there soil moisture can be maintained only within certain ranges from the field capacity down to specified minima. The establishment of controlled experimental conditions is even more difficult in regions where frequent and irregular summer rainfall occurs. These difficulties in establishing controlled experimental conditions, the labor and expense in attempting to follow accurately the amount of soil moisture present and tree response, and the thought that finally in many regions soil moisture is beyond the control of the grower have resulted in some neglect on the part of research workers in attacking this problem. Because of the intimate relationship between moisture supply to the tree and all phases of fruit-tree functioning, however, researches to determine the response of the tree to different moisture conditions in various soils and environments are essential to intelligent orchard management, both under irrigation and under non-irrigation conditions.

Our knowledge of the soil as a reservoir for water is based on the work of many investigators, both in Europe and in the United States. As a result, we know that with good drainage conditions any particular soil will take up and hold against gravity only a certain rather definite amount of water. This amount is termed the *field capacity* and varies widely with soils differing in texture and structure. In general the finer-textured soils have the higher total water-holding or field capacity.

The work of Briggs and Shantz (5) supported by many investigators since has clearly demonstrated that a certain proportion of the water held in any soil is not available for plant usage. The moisture content of a soil at which a plant wilts when growing under conditions of limited transpiration and at which it does not recover turgidity without the addition of water is termed the *wilting co-*

efficient or the *wilting percentage* of that soil. This wilting percentage varies also with the soil type but does not vary appreciably with the kind of plant growing in the soil. The wilting percentage is apparently determined largely by forces within the soil itself rather than forces within the plant. Maximov, (17) and later Shull, (21) have suggested what appears to be a very plausible explanation of this phenomenon, namely, that at the wilting percentage capillary movement of moisture in the soil ceases and that therefore there is no longer any movement of moisture from soil particles not in actual contact with young roots or root hairs to those soil particles that are in such contact. Investigations on the osmotic concentration in the epidermal cells of roots indicate that roots should be able to absorb moisture from the soil at points below the wilting percentage. Therefore, the wilting percentage apparently is not the point at which the maximum osmotic concentration of the plant and the forces holding water in the soil come into balance. The osmotic concentration in the roots should still result in water being taken into the plant at or below the wilting percentage but some factor, probably that of lack of water movement in the soil at these low concentrations, prevents water intake.

The amount of water remaining in the soil at the wilting percentage also varies with soil texture and structure, in general the amount of moisture at the wilting percentage being highest in the fine-textured soils and lowest in the coarser soils. With very fine-textured soils such as sticky clays the wilting percentage is likely to be approximately half of the field capacity, although soils are known in which the wilting percentage is even higher relative to field capacity. With the coarser soils the wilting percentage will generally be less than half of the field capacity. On the average a somewhat higher proportion of the field capacity is likely to be available for plant usage in the coarser-textured soils. Because of the much greater total field capacity, however, the total amount of water which may be stored available for plant usage is generally higher in the finer-textured soils and decreases as the soils become coarser.

From the orchardist's standpoint, particularly where irrigation is not practiced, the most satisfactory soil is, therefore, one that has a fairly wide range between field capacity and wilting percentage or one that will store a large amount of water available to the plant. This water storage capacity must be coupled, however, with good drainage so that the soil will not be water-logged at any season of the year and thus prevent root penetration. The moderate clays or clay loams are excellent if well drained, as when underlaid at a depth of several feet with gravel or shale. In general, silt loams combine excellent available moisture storage with good aeration and drainage. Sandy and other light soils are generally inferior from the moisture-holding standpoint and will be satisfactory without irrigation only if of unusual depth or if underlaid with clay to give increased water-storage capacity. Where maximum water storage is less important, as in irrigated regions, the moderate or lighter-texture soils may have other important advantages from the orchard standpoint, as will be mentioned later.

It should be emphasized that the field capacity and the wilting percentage of a soil are based on the texture and structure of that soil and are not subject to wide modification by any practical operations that the orchardist can perform. The statement has often been made, rather loosely, I believe, that we can increase the water-holding capacity of the soil by adding organic matter. The addition of organic matter does to a degree increase the water-holding capacity. The incorporation of even large amounts of organic matter in the surface 6 or 8 inches of the soil will not greatly increase the total amount of water that can be held in the soil mass. Of greater importance from the moisture standpoint than actually increasing water-holding capacity is the value of organic matter in improving absorption and penetration of water and thus preventing run-off. Also, of course, the great nutritional value of organic matter is generally recognized. We should realize, however, that we can not, within reasonable limits, change the basic structure of a soil or change greatly its water-holding capacity. Unless the soil is basically satisfactory from the standpoint of water-holding capacity and depth, it should not be planted to orchards.

Also, it must be emphasized that in reporting soil moisture studies, figures giving percentages of moisture present, without a knowledge of the wilting percentage of the soil, generally mean little. The wilting percentage of some soils is far higher than the field capacity of others. The important factor in soil moisture research and plant response is not how much water, but how much available water, is present.

Withdrawal of Water by Trees

The distribution of the root system largely determines from what soil zones and areas moisture will be absorbed. Investigations by Conrad and Veihmeyer (6), and by Aldrich, Work and Lewis (3), have indicated that the relative rate of water absorption from different soil areas, so long as moisture is available throughout the root zone, is almost directly proportional to the density of the feeder root population in those areas. The work of McLaughlin (19), and of Veihmeyer and Hendrickson (22) has indicated that the importance of the capillary movement of water in soils in carrying the water from considerable distances to the roots of the tree has been over-emphasized. These investigations indicate that the water supply to the tree must come from sources fairly close to the roots and that the water is taken largely from soil areas directly occupied by roots. While this work has been outstanding in demonstrating that water does not move readily by capillarity through long distances in the soil, we believe there is danger of misunderstanding if the role of capillarity is assumed to be negligible. It is only in light and well aerated soils that we ever have a root distribution in the orchard that even approaches complete occupation of the soil. The withdrawal of water from distances of even a fraction of an inch from the roots must depend upon capillary movement to carry the water to the roots. The results of Shaw and Smith (20) would indicate that water may move for distances of one or two feet in soil at a moderately rapid rate especially when the soil moisture content is appreciably above the wilting per-

centage. Therefore, it seems probable that capillarity is of great importance in the supplying of water to the roots from soil short distances away. We have indicated above the possible significance of this from the standpoint of the wilting percentage of the soil.

The evidence strongly indicates, however, that in most soils water is taken up primarily from zones actually occupied by roots and in approximate proportion to the density of root population. It is therefore of great importance to know something of the root population in the different zones in various types of orchard soils. Investigations in New York, Ohio, Michigan, and other eastern States as well as in the West in recent years have greatly increased our information on this question of root population in different soil zones or horizons and in different soil types.

In general on heavy soils in the eastern States, particularly if poorly drained, a great proportion of the roots is in the surface foot or 18 inches. On lighter, well drained soils, root distribution is more nearly uniform down to a depth of several feet although even in such soils the densest population is near the surface. In regions of relatively light rainfall and in fairly open soil, root penetration down to 20 or more feet is not unusual.

In the irrigated districts of the West on medium-textured soils, root penetration may be very deep, and a great concentration near the surface does not normally occur although even there the surface foot is likely to carry the greatest root population. It is probable that on our well drained, sandy soils in the eastern States root distribution would be somewhat more uniform and deeper than has generally been found on the heavier soils which have had more study. Thus the uniformity of root distribution as well as the total depth to which roots penetrate will vary greatly in different types of soil.

As moisture in the soil is reduced by the trees, the zones of greatest root concentration reach the wilting percentage first, followed by those of decreased population. Only a few scattered roots reaching into areas of available moisture may supply sufficient water to maintain life in the trees for considerable periods after fruit growth has ceased. The work of Auchter (4) and of Furr and Taylor (10) has shown that there is a free movement of water throughout the tree and that water supplied by roots in one area is apparently equally available to all parts of the tree top.

Relation of Soil Moisture Supply to Tree Functioning

The amount of water which must be supplied from the soil to maintain a tree in optimum functioning condition is not constant throughout the growing season or even from day to day. As Livingston and his associates, as well as many other workers have emphasized, the water requirement of the plant varies greatly with the evaporating power of the air. What has been termed the efficiency of water or the amount of dry matter which can be formed in a plant per pound of water used varies with atmospheric conditions, the greater the evaporating power of the air the lower being the water efficiency of the plant. Under conditions of high humidity relatively little water is transpired and the tree may function at the optimum

rate even with little water being supplied from the soil. Under conditions of normal summer transpiration, there is a wide fluctuation during the day in the demand of the tree for water. With most of our fruit trees, water is not supplied to the tree sufficiently fast by the soil and roots to maintain maximum efficiency throughout the day under conditions of even moderately high transpiration. In investigations with apple trees in the Middle Atlantic States as well as in the West, we have found that stomata rarely remain open later than noon on bright, clear days regardless of the soil moisture condition. On cloudy or rainy days, on the other hand, most of the stomata will remain open throughout the day. We have found (16) a reduction of as much as 10 per cent in the amount of moisture present in the leaves between sunrise and mid-afternoon. Also, during the afternoon, fruit-volume increase usually slows down or fruit enlargement may cease for a period of several hours. With citrus fruits, definite shrinkage frequently occurs so that some orchardists limit fruit picking to the morning hours. Thus it is apparent that, under conditions of moderately high transpiration, water is not supplied to the foliage in sufficient quantities to result in the stomata remaining open and to permit leaves to function fully throughout the full daylight period, regardless of soil moisture conditions. With the closing of the stomata in the evening and with the reduced evaporating power of the air which normally occurs at night, the water supply to the leaves, bark, and other organs is restored provided sufficient soil moisture is available.

The picture of the fruit tree in relation to moisture, therefore, is not one of a uniform condition in the tree so long as soil moisture is available. With sufficient soil moisture, tree tissues are turgid in the morning, stomata open and, so far as we know, the physiological processes of photosynthesis and related activities proceed at the maximum. Some time during the day, moisture supply to the leaves generally becomes so reduced that stomata close, also fruit enlargement may cease temporarily and the tree can be considered in a state of greatly reduced physiological activity until turgidity of tissues is again restored. The length of the period of reduced physiological activity during any day will depend upon two factors: (a) the rate at which water is supplied by the soil, and (b) the evaporating power of the air.

We would not, of course, imply that the physiological processes in the plant cease completely when the stomata are closed. Also, under certain conditions a portion of the stomata remains open throughout the day although most of them may be closed. We do not know how physiological processes other than photosynthesis are affected by temporarily reduced water supply in the leaves and bark. We believe that there is ample evidence to indicate that photosynthesis at least is greatly reduced under these circumstances.

Measurements of fruit taken in the orchard at intervals of several days actually represent total growth during several periods of rapid and slow enlargement. Aldrich and Work (2) at this meeting have presented evidence that pears in very heavy clay soil show a reduced growth rate during periods of several successive days of extremely high transpiration even with soil moisture highly available. Similar,

but much less pronounced results, were obtained on a lighter, sandy loam soil. Commercial experience in the irrigated districts has been that fruit-growth rate seems to decline when transpiration and temperatures are extremely high. While this may be due in part to the direct effect of high temperature, the evidence from stomatal behavior would indicate that it is also due in part to water shortage in the tree during longer periods each day under such conditions.

The results of Hendrickson and Veihmeyer, (13) (14) mostly obtained on moderate-textured to light soils in California, have indicated that fruit trees have functioned about equally well whether the soil moisture was near field capacity or approaching the wilting percentage. Results of Harley and Masure (12) with apples on similar type soils at Wenatchee, Washington, and of Cullinan and Weinberger (7) on peaches in Maryland on a moderately light soil have in general been in agreement with the California results. Thus on moderate to light soils, water is apparently supplied to the tree about as rapidly when the soil is approaching the wilting percentage as when it is near field capacity. On the other hand, the work of Lewis, Work, and Aldrich (15) on very heavy clay adobe soils near Medford, Oregon, has indicated that tree functioning of pears on those soils is reduced before any portion of the root zone based on soil moisture determinations approaches even close to the wilting percentage. Results of Furr and Magness (9) and of Furr and Degman (8) indicate that on well drained, moderately heavy shale clay soil in western Maryland, the fruit growth rate of apples was reduced while soil moisture in the surface foot of soil was measurably above the wilting percentage.

Experimental evidence obtained to date would indicate that maximum functioning of orchard trees in very heavy soil under conditions of moderately high transpiration occurs only if soil moisture is on the average much above the wilting percentage. Trees in light soil, on the other hand, can obtain moisture in sufficient amount to permit optimum functioning until the wilting percentage is approximately reached, at least in the zone of maximum root concentration. Response of trees on soils of intermediate texture tends to fall between these extremes. A consideration of some known principles of root development and moisture behavior in the soil suggests an explanation of these results.

As stated above, on moderate to light and well drained soils, root distribution in the soil is generally much more perfect and soil particles on the average are closer to feeder roots. Also, the capillary movement of moisture in such soils, according to McLaughlin's (19) results, is likely to be more rapid than in very heavy soils. Under these conditions the soil will supply moisture to the roots at near the required rate for optimum functioning of the tree so long as moisture supply is measurably above the wilting percentage. With very heavy soils, on the other hand, with a less perfect root distribution and with slower capillary movement through the soil the rate of water supply to the roots is apparently reduced when the soil mass as a whole has a large amount of available water still present. It seems probable that the soil in immediate contact with roots under these conditions may be relatively much drier than that even a short distance away which

supplies water only by capillarity. Soil samples at the best can only represent an average of the moisture condition in a considerable mass of soil. We need much more evidence on the rate of capillary movement of moisture in soils of different texture. It seems probable that the rate that water is supplied to roots by the soil depends in considerable part upon the rate of this capillary movement. Thus a heavy soil will apparently supply water more slowly but for a long period, while a light soil may supply water much more rapidly with the available supply being rather quickly used up by the trees. If the water supply of such medium to light-textured soils can be replenished as needed, they are ideal for fruit production. With extremely light soils it is difficult to maintain sufficient soil moisture even with irrigation.

When a portion of the root zone reaches the wilting percentage we have no evidence under orchard conditions to indicate that the rate of absorption in other parts of the root zone is increased. If the rate of moisture uptake is determined by conditions within the tree it would appear that the moisture intake in that portion of the root zone having water still available would be increased when such conditions develop. It seems probable from theoretical considerations that this would be the case provided the remaining portions of the root zone were abundantly supplied with moisture. Under actual orchard conditions, however, by the time a portion of the root zone reaches the wilting percentage the available water in most of the remainder will also be greatly reduced. Under these conditions it seems probable that the rate of capillary movement in the soil rather than the rate of absorption and translocation of water by the plant determines the possible intake and that therefore the water intake is not increased in other areas when a portion of the root zone reaches the wilting percentage. Under such conditions the total water supply to the tree is reduced and the functioning of the tree will be reduced in proportion as the water supply becomes more and more limited.

Effect of Water Shortage on Nutrition of Fruit Trees

The most sensitive criterion of the moisture condition in our fruit trees that we have been able to determine is the number of stomata which open and the length of time they remain open. Except under conditions of acute moisture shortage there is generally a sufficient accumulation of water in the leaves during the night to permit the opening of the stomata in the morning. Under conditions of progressive reduction in moisture supply to the leaves the stomata will close earlier and earlier in the day. It is possible to detect differences in stomatal behavior correlated with differences in soil moisture supply much earlier than it is possible to determine differences in fruit growth rate.

Reduction in fruit growth rate, at least with apples and pears, is an early indicator of insufficient water for maximum functioning of the tree. Unless unusually high transpiration conditions occur, any reduction in growth rate of these fruits on a volume basis during the period from bloom until near harvest is an indication that water supply probably is becoming limited, assuming of course that foliage has

not been attacked seriously by insects or diseases. With peaches, the situation is complicated by the various growth periods of the fruit, but the same condition holds particularly during the period of final rapid swell.

As more and more of the root zone reaches the wilting percentage on lighter-type soils or approaches it in heavy soils, the rate that moisture can be supplied to the tree decreases accordingly and the daily period during which the foliage and other tree parts are functioning also decreases. When most of the root zone has reached the wilting percentage, tissues of the tree fail to become fully turgid even at night. Under these conditions, stomata may fail to open in the morning, growth of fruit ceases, and definite shrinkage of fruit may occur. Fortunately even under such conditions fruit trees growing in the open soil will survive for considerable periods of time. Probably under these conditions a few roots that have penetrated deeply obtain water at least in sufficient quantities to prevent the death of the tree.

As mentioned earlier, under conditions of decreasing moisture supply in the soil the osmotic concentration in the epidermal cells of roots of other plants has been found to increase. We have found (16) that one outstanding effect of prolonged periods of moisture shortage in apple trees is an increase in the concentration of soluble carbohydrates in the tissues. This increased concentration of soluble carbohydrates accompanies a change in the starch-sugar ratio, starch storage in the tissues showing a marked reduction while the sugar content increased.

We have not determined how rapidly this change may occur. It is very apparent after the cumulative effect of several weeks of tree functioning under reduced moisture supply. Whether it may also occur to a more limited extent as a result of the daily period of reduced moisture supply to the tree has not been determined. The cumulative effect of an appreciable period of moisture shortage is, however, to increase the concentration of soluble carbohydrates in bark, wood, and fruit with an even greater decrease in the amount of starch in these same tissues.

Under such conditions of prolonged water shortage there is apparently a marked decrease in total carbohydrate synthesis correlated with the reduced daily periods of stomatal opening. The total carbohydrate content of wood and bark following a period of moisture shortage is lower, notwithstanding the fact that carbohydrate usage during the same period is also greatly reduced in such trees due to reduced growth rate of fruit and vegetative tissues. The literature on this apparent correlation between stomatal closure and reduced carbohydrate synthesis has been reviewed by Maximov (18). In fruit trees as in annuals, a moisture shortage apparently results in a great reduction in total carbohydrate manufacture.

Increased fruit-bud formation following drouth conditions has been a common observation among orchardists. Twenty years ago Gourley (11) called attention to the increased fruit-bud formation following early-season drouth in apples. Aldrich and Work (1) have recently found complete substantiation of this relationship in pears. Our own experiments, as well as observations in apple and peach orchards fol-

lowing the early drouth of 1930, would bear out these results. Apparently conditions of moisture shortage occurring while the buds are still in meristematic condition tend to result in increased formation of fruit-buds. These results would indicate that if carbohydrate accumulation is the controlling factor in the initiation of flower parts the soluble carbohydrates are of primary importance. In this connection, however, we should state that we have not always been able to correlate fruit-bud formation with the presence of abundant soluble carbohydrates in apple tissue.

One of the most remarkable factors in the relation of the tree to moisture supply has been the recovery of the functioning of trees when moisture is supplied after periods of moisture shortage. In some experiments the moisture supply of trees has been reduced until practically no fruit growth occurred during periods of as much as two weeks, and during most of this time the trees were in a definitely wilted condition. Functioning of trees that did not lose a large amount of foliage was immediately restored when water was supplied and fruit growth was resumed at a rate practically equal to that on trees which had not suffered for water. The immediate effect of supplying moisture under such conditions is likely to be an even faster increase in size of fruit on drought trees than on those well supplied with water for a short period, probably due largely to the restoration of turgidity. The fact that trees following such extreme water shortage are able to resume normal functioning almost immediately after water is supplied is of great interest and is particularly fortunate for the orchardist.

Following conditions of moisture shortage, however, the size of the fruit will be reduced in approximate proportion to the length of time during which growth was restricted. If this occurs in peaches during the period of final swell, the size of fruit will be greatly restricted. With apples we find the growth rate of fruit on a volume basis almost uniform from a period of approximately 50 days after bloom until harvest time. During this period with long-season varieties, the fruit will grow approximately one per cent of its final size per day if conditions are favorable. With summer varieties the growth rate is even more rapid. Thus the total decrease in the size of the fruit at the end of the season due to conditions of acute moisture shortage at any time during the season can be fairly accurately estimated.

We do not know what the carbohydrate situation is in fruit trees during the winter months following summer drouth. With reduction in carbohydrate manufacture in excess of the reduction in usage, we would expect reduced total carbohydrate in the tree in winter and consequent greater susceptibility to winter injury, such as follows the production of heavy crops. Analyses of such material have not been made to date in our work.

We have not found a significant variation in nitrogen content of tissues following variations in moisture supply to the trees. Analyses to determine this have not been sufficient to reach definite conclusions, however.

In conclusion we would emphasize the many phases of the problem of moisture relation in the orchard which need more research. Par-

ticularly we need to know more of the water supplying power of different soils. Perhaps in that will be a basic contribution on the value of different soil types for fruit production. We need to know more of the water intake and translocation in the plant and of the forces involved. We need particularly far more information than is now available on the relation of moisture to the nutrition of the tree. We need far more data on the directly applied phases of the problem—on the effect of cover-cropping, mulching, and other management practices on moisture supply. We need to know our orchard soils better—their field capacity, wilting percentage, available water-holding capacity. These data, coupled with depth and drainage, should make possible a determination of the value of soils for orcharding before, rather than after, they are planted.

We would like to emphasize that from the moisture standpoint a tree is never the same two days in succession, or even two hours, because of the wide variation in water demand. In the final analyses we must depend upon studying the tree to determine if it is getting sufficient water for optimum functioning rather than studying the soil.

Finally, I would congratulate the many workers in this field for the progress that has been made, particularly in recent years. In spite of many limitations and imperfect information on many phases of the problem, the story of the inter-relations of moisture supply and tree function is steadily unfolding.

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